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Technical Report 565

**A FORECAST OF ARMY AVIATION TRAINING
RESEARCH AND DEVELOPMENT
REQUIREMENTS FOR THE
PERIOD 1985 TO 2000
VOLUME I**

Ralph C. Lenz, Kuei-Lin Chen, John A. Skerl
Richard L. Newman, Loren A. Anderson, Robert L. Warner
University of Dayton Research Institute

ARI FIELD UNIT AT FORT RUCKER, ALABAMA

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This research report identifies U.S. Army aviation system and subsystem ac- quisitions projected for the time period of 1985 to 2000 which will require behavioral research to support development of new aircrew training methods and equipment. The report describes the conduct and results of three tasks: (a) a survey to identify future Army aviation related systems and subsystems; (b) the identification of systems with unique training needs; and (c) the determination of training requirements and the forecasting of behavioral		

Item 20 (Continued)

research requirements for the systems with unique training needs.

This research is intended to assist the Army in identifying behavioral research requirements for future Army aviation aircrew training before the new aviation systems and subsystems are introduced. The lead time provided by the early initiation of behavioral research programs should aid the development of effective training systems. Requirements for the behavioral research needed to support Army aviation training programs in the time frame 1985 to 2000 are described in this report. This document presents an integrated and future-oriented review of U.S. Army aviation training R&D needs.

The appendix (published as ARI Research Note 82-29) presents the survey results in questionnaire format, as they were originally obtained, together with information on scoring model weighting, and a complete listing of the bibliographical references.

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FOREWORD

The Army Research Institute Field Unit at Fort Rucker, Alabama, has the mission of providing timely research and development support in aircrew training for the U.S. Army Aviation Center. Research and development are conducted inhouse, augmented by contract research as required. This research report documents work done under contract by University of Dayton Research Institute as a part of the Field Unit's effort to remain proactive in responding to future training needs in Army aviation.

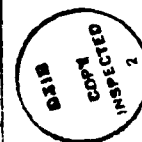
The report identifies for the period 1985-2000 aviation systems with unique training needs and the training requirements for these systems. Personnel affordability for these systems is also discussed, but not in detail.

This effort is responsive to Army Project 2Q763743A765 and to the U.S. Army Aviation Center, Fort Rucker, Alabama.



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Technical Director

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Special thanks are due to people who participated in survey interviews and generously contributed their knowledge and comments on training requirements, which helped us greatly in the selection of aviation systems and subsystems for detailed analyses. The aviation experts who participated in survey interviews were:

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Major T. J. Roop	(TRADOC, Ft. Rucker)
Don Artis	(TRADOC, Ft. Rucker)
Lt. Col. Richard L. Walburn	(DARCOM, St. Louis)
Major James P. Bell	(DARCOM, St. Louis)
Lt. Col. J. Turnage	(DARCOM, St. Louis)
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Charles Johananigmeier	(AVRADCOM, St. Louis)
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Sam Hurt	(AVRADCOM, St. Louis)
William Brabson	(AVRADCOM, St. Louis)
Fred Cappetta	(AVRADCOM, St. Louis)
Randy Vause	(AVRADCOM, St. Louis)

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A FORECAST OF ARMY AVIATION TRAINING RESEARCH AND DEVELOPMENT REQUIREMENTS
FOR THE PERIOD 1985 TO 2000. VOLUME I

EXECUTIVE SUMMARY

REQUIREMENT:

To identify U.S. Army aviation system and subsystem acquisitions projected for the years 1985 to 2000, and the associated requirements for behavioral research needed to meet new training requirements for these acquisitions.

PROCEDURE:

The project started with on-site interviews with Army personnel at various developing agencies and commands, to identify aviation systems and subsystems that would be introduced during the period 1985 to 2000. Survey interviews were conducted with Development and Material Readiness Command project managers, Training and Doctrine Command system managers, and Army Aviation Research and Development Command engineers and scientists.

A list of future Army aviation systems and subsystems was developed from the survey results. Scoring models were used to analyze information collected in the survey. The relative importance of each system and subsystem to future Army aviation operations was considered, system elements which will require different or new training were reviewed, and training requirements were defined.

Some factors which may affect the size and characteristics of the future trainee population were examined because trainability of the available personnel is one of the key dimensions for training research. Although the scope of this project did not permit the extensive analysis which this subject deserves, the importance of some factors became apparent in the review of available data. These limited findings are documented in the report.

A comprehensive literature search was conducted on several data bases to identify the extent of behavioral research in various areas related to aviation aircrew training requirements. Finally, behavioral research requirements for meeting future training needs were forecast, using the results of the analysis of survey information and the review of literature on related behavioral research.

FINDINGS:

The survey indicated unanimous agreement that the importance of physical skills in flying will be reduced while the decision-making workload will increase, so that Army aircrews will continue to perform near the upper limit of their abilities. Cockpit information clutter will be reduced by the substitution of cathode ray tube (CRT) displays for dial systems.

The mast-mounted sight and other new targeting sub-systems will revolutionize combat capabilities and substantially increase the amount of training required for night and adverse weather operations. These subsystems will provide substitute cues for flight and combat operations which will require training changes. Pilot orientation to images in different coordinate systems may result in vertigo or other adverse reactions. Air-to-air combat training

will be necessary but difficult to establish because of the absence of doctrine based on combat experience.

The scoring model evaluation, and the data on training-related characteristics of each of the items of Army aviation equipment reviewed, may be used as a basis for determining the needs for new training approaches for each system or subsystem. The CRT displays will shift training emphasis away from cockpit familiarization toward recognition of information needs and ability to establish decision-aiding information flows. Cockpit automation will accelerate the trend toward computer-recorded performance and computer-assisted instruction and training in the air and on the ground.

Because many combat tasks will be performed through the use of electronically-gathered information, the use of part-task trainers which simulate only the display and associated task controls, should be studied for these tasks. Adverse weather operations, night nap-of-the-earth (NOE) flight, and rapid deployment will require new training methods and an increasing proportion of total training time. In addition, night operations may require selection of personnel who have special aptitudes in this area.

Reductions in the number of Army personnel accessions relative to personnel demands may require changes both in selection criteria and in training methods. The currently used model for predicting Army personnel accessions is likely to seriously underestimate probable accessions because the population base on which the model is based is dramatically different from that which will exist in the 1982 to 2000 period.

Recommendations for research include the following: (1) better definition of the appropriate balance between simulator training and flying training, with specific consideration of aircrew psychological needs for actual flying; (2) behavioral research on practical integration of visual, auditory, and tactile sensory inputs in cockpit design; (3) research on factors relevant to aircrew behavior at the break point of workload saturation; (4) examination of possible gains from reversal of the training sequence, i.e., having instrument flight training in simulators precede visual flight training; (5) research on piloting requirements for NOE operations in environments offering minimal concealment and in areas dominated by man-made structures; (6) research on behavioral factors involved in close-formation helicopter flight operations; (7) identification of methods of measuring aptitudes for information processing and combat decision-making; (8) development of a fundamental understanding of human responses to presentations of task-related visual abstractions, to support development of CRT-displayed cueing systems; and (9) research to determine the characteristics of mission-related information which should be provided in map-type displays, particularly for NOE operations.

UTILIZATION OF FINDINGS:

The findings are intended to assist the Army in identifying aviation aircrew training research and development requirements for the period 1985 to 2000.

A FORECAST OF ARMY AVIATION TRAINING RESEARCH AND DEVELOPMENT REQUIREMENTS
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SECTION 1 INTRODUCTION

This research project was designed to identify U.S. Army aviation system and subsystem acquisitions projected for the time period 1985 to 2000 which will require behavioral research to meet new training development needs. The project consisted of three tasks: (a) a survey to identify future Army aviation related systems and subsystems; (b) the identification of systems with unique training needs; and (c) the determination of training requirements and the forecasting of behavioral research requirements for the systems with unique training needs. In addition to these three tasks, a limited amount of data was developed concerning the issue of personnel availability. Further consideration of this issue is important in terms of its relation to personnel qualifications and their consequential effect on training needs.

The results of the project are intended to assist the Army in identifying behavioral research requirements for future Army aviation aircrew training before the new aviation systems and subsystems are introduced. The completion of behavioral research programs should aid the development of effective training programs.

The University of Dayton research project team conducted on-site interviews with Army personnel at various agencies who are responsible for or are participating in the development of future Army aviation and related systems and subsystems. A survey questionnaire was developed for the interviews and documents on Army aviation R&D programs were reviewed [1,2] to identify the principal aviation systems and subsystems which are expected to be introduced in the future. The survey questionnaires also were used to obtain Army aviation experts' opinions on differences in training, new training needs, and potential behavioral research requirements.

The extensive literature review identified the behavioral research work which has been accomplished in this field and revealed the areas where further behavioral research is required. The literature review disclosed a long history of Army involvement in research concerning aviation training, generally with a narrow focus on single issues. Only a few research efforts examined overall training issues, training needs, or behavioral research requirements for future Army aviation training.

The Conference on Aircrew Performance in Army Aviation, held at the U.S. Army Aviation Center, Ft. Rucker, Alabama on November 27-29, 1973 was the most comprehensive previous effort to analyze Army aviation training issues and behavioral research requirements. Participants in this conference recommended a behavioral research program [3] to support Army aviation training needs. Aviation systems and subsystems considered in the 1973 conference are not the same as those examined in this report. Nevertheless, certain recommendations made in that conference are still applicable to future Army aviation operations.

New behavioral research requirements to enhance Army aviation training programs in the time frame 1985 to 2000 are described in this report. This document presents an updated and integrated review of future U.S. Army aviation training R&D needs. Subsequent to the completion of the survey and

most of the analysis upon which this report is based, a U.S. Army Aviation Training Symposium was held on December 1-3, 1980, at Fort Rucker, Alabama.[4] The report from that symposium is, of course, also relevant to many of the items in this document.

SECTION 2 METHODOLOGY

2.1 DATA COLLECTION REQUIREMENTS

The first task was to determine what information needed to be collected. Since the goals of the project involved prediction of changes, information about the present state of Army aviation and possible future states (to the year 2000) was necessary. A flow of questions emerged: What are the present Army aviation systems and subsystems and what are the projected future Army aviation systems and subsystems? How do the hardware and operations of the present and future differ? What changes in training methods are going to be required because of these differences? What behavioral research is required to prepare for new training methods? What will be the characteristics and qualifications of Army aviation trainees?

For each of the systems and subsystems, information was needed about hardware, performance, cockpit crew operations, and battle operations. Finally, to gauge the possible impact of new systems and subsystems on the Army, information was needed about scheduled years and probability of adoption, and extensiveness of use. Specifically excluded from consideration were fixed wing aircraft and maintenance requirements.

2.2 SURVEY INSTRUMENT

Once the categories of information were determined, the challenge was to develop an interview questionnaire which could be completed in approximately one hour. A flow chart, seeking data on the old and new systems and their differences, was very useful in formulating early drafts of the questionnaire. The basic flow of questions was: What are the characteristics of the present system (if one exists)? What will be the characteristics of the future system? What are the differences in these characteristics? What are the training requirements for the present system? What will be the training requirements for the future system? What are the differences in the training requirements?

Asking each of these questions about all components of each system and subsystem would have resulted in an unmanageable questionnaire. Therefore, the decision was made to focus attention only on differences (and not on all characteristics of the present and future systems), and only on differences which were radical enough to require the alteration of training methods. Determining the degree of difference was accomplished by use of Likert-like response categories:

- (a) radically different,
- (b) substantially different,
- (c) somewhat different,
- (d) minimal or no difference.

Those characteristics rated either "radically different" or "substantially different" would be explored further by using open-ended questions. A determination would be made of whether characteristics rated "somewhat different" would require alteration of training methods. If an alteration was

foreseen, the nature of the difference would be further explored by using open-ended questions.

After defining the content and approaches to gathering information, an outline for the final questionnaire was developed:

I. BASIC INFORMATION

- (a) Identification of Future Systems and Major Subsystems
- (b) Probabilities of Introduction
- (c) Scheduled Years for Introduction
- (d) Extensiveness of Use
- (e) Current Systems to be Replaced or Supplemented

II. DETAILED INFORMATION COMPARING EACH NEW SYSTEM WITH THE PRESENT SYSTEM

- (a) Physical Characteristics
- (b) Performance
- (c) Cockpit Crew Operations
- (d) Combat Operations Tasks
- (e) Man-Machine Skill Requirements
- (f) Crew Interaction
- (g) Training Methods

The final draft of the questionnaire was then composed and formatted. Identifying information questions were added at the beginning, and an open-ended "catch-all" question was added at the end. Completed copies of the final questionnaire are included in Appendix A, and the questions are synopsized in Table 3, Section 2.3.2.

Eleven interview sessions involving 14 interviewees were conducted. The interviews took place at Fort Rucker, Alabama on May 6 and 7, 1980 and in St. Louis, Missouri on May 27 and 28, 1980. Personnel from TRADOC, AVRADCOM, and DARCOM were interviewed. Three of the interview sessions involved two interviewees. One to five interviewers conducted each of the interviews, which lasted approximately 90 to 120 minutes. A list of the interview sessions and the systems discussed is contained in Table 1. In sessions involving more than one interviewer, each interviewer independently recorded responses, which later were cross-checked and consolidated.

2.3 THE SCORING MODEL

2.3.1 Scoring Model Concept

The basic idea for the scoring model is to score a situation on each of a number of factors, and then combine the individual scores into a single composite score. The survey produced both objective data and judgmental opinions. Objective data included such examples as the projected date of introduction of a new aviation system and the expected quantities to be procured. These objective data were converted into scaled scores for use in the model. Judgmental information included items such as the degree of difference in physical or performance characteristics between a current aviation system and a future system that will replace it. The judgmental data

TABLE 1
AGENCIES INVOLVED IN THE INTERVIEW SURVEY

Interview Session	Organization	Systems/Subsystems Discussed	Date of Interview
1.	TRADOC, Ft. Rucker	Near-term Scout Helicopter	5/06/80
2.	TRADOC, Ft. Rucker	Attack Helicopter	5/06/80
3.	TRADOC, Ft. Rucker	LHX-Scout SEMA-X	5/06/80
4.	PMO for ASH DARCOM, St. Louis	Near-term Scout Helicopter Advanced Scout Helicopter	5/28/80
5.	PMO for Black Hawk DARCOM, St. Louis	Black Hawk	5/28/80
6.	AVRADCOM, St. Louis	Aircraft Rocket Subsystems Aircraft Guns Subsystems Fire Control	5/27/80
7.	AVRADCOM, St. Louis	ADAS, Landing Subsystems	5/27/80
8.	AVRADCOM, St. Louis	LH-X SEMA-X	5/27/80
9.	PMO for AAH, DARCOM, St. Louis	AAH	5/28/80
10. & 11.	AVRADCOM, St. Louis	ADOCS IDSV	5/27-28/80

were scaled for use in the model. This objective and judgmental information was combined in the scoring model. The model output provided several measures of the relative importance of new systems and subsystems with respect to the effects which they will have on training and on the need for behavioral research. Throughout this report the term "importance" is used with this meaning and in this context.

The scoring model combined the judgments of several persons, and thus obtained a composite judgment. The model structure focused the attention of each survey respondent on those facets of the problem which he knew the most about. The factors were then combined into an overall or composite opinion.

There are two basic types of scoring models, the additive and the multiplicative. For either type, a set of factors, X_1, X_2 , etc. is identified which includes all the factors of interest in the situation being modeled. Each factor is associated with a weight a_1, a_2 , etc., such that a_1 represents the relative importance of X_1 , a_2 the relative importance of X_2 , etc. In the additive type of model, the composite score S is formed as:

$$S = a_1X_1 + a_2X_2 + \dots + a_nX_n.$$

In the multiplicative model, the composite score S is formed as:

$$S = (X_1^{a_1}) (X_2^{a_2}) \dots (X_n^{a_n}).$$

If a low score on one factor can be offset by a high score on another factor, the additive model is appropriate. If a low score (especially a zero) in any factor can override a high score on any or all other factors, the multiplicative model is appropriate. Thus, the form of the model must be appropriate for the situation. A compound model including sum-of-products and product-of-sums was developed for this analysis as described in the following sections.

2.3.2 Construction of the Scoring Model

The scoring models used in this study are designed to interpret the importance of various features of future aviation systems in relation to changes required in air crew training. The inputs to the scoring models are based on information gathered through the interview survey conducted as part of Task 1. The questionnaire discussed in paragraph 2.2 was used to collect information on future Army aviation systems and subsystems expected to be in the inventory for the years 1985 to 2000. In the survey, we examined the systems and subsystems listed in Table 2. The definition of "systems" and "subsystems" indicated here, and used throughout the report, is as follows. "Systems" are defined as helicopters designed for Army aviation missions, complete with all components normally required to accomplish the specified missions. "Subsystems" are portions of such systems, which may be complete in themselves, but which must be integrated with other subsystems to enable mission accomplishment. Many such "subsystems" are often identified in

TABLE 2
ARMY AVIATION SYSTEMS AND SUBSYSTEMS

System ID

- | | |
|---|---|
| 1 | LHX - Scout 1990's/Advanced Scout Helicopter |
| 2 | SEMA-X (Special Electronic Missions Aircraft) |
| 3 | Black Hawk (UH-60) |
| 4 | Advanced Attack Helicopter (AH-64) |
| 5 | Near-term Scout Helicopter |

Subsystem ID

- | | |
|----|---|
| 11 | ADAS (Army Digital Avionic System) |
| 12 | Landing Subsystems |
| 13 | Aircraft Rocket Subsystems |
| 14 | Aircraft Guns |
| 15 | Fire Control/Mast Mounted Sight, FLIR, Laser |
| 16 | ADOCS (Advanced Digital Optical Control System) |
| 17 | IDSV (Integrated Digital Systems Validation) |
-

official DoD nomenclature as "Systems." Consistency in this analysis required that complete "systems" be distinguished from portions thereof, i.e., "subsystems." However, we did not believe it within our prerogative to alter official nomenclature; therefore, some items retain the designation "System" in their title.

Objective data collected included the expected years for new system and subsystem introduction in the Army inventory, their degrees of anticipated usage in Army aviation, and the probabilities of introducing these new systems. Judgmental data collected from the questionnaire concerned degrees of difference between new systems and their corresponding current systems in terms of physical characteristics, system performance, cockpit crew operations, combat operations tasks, man-machine skill requirements, crew interaction requirements, and training methods. The specific questions asked are listed in Table 3. These objective and judgmental inputs were used as elements in the scoring model.

2.3.2.1 Basic Factors

We treated data from Questions 2, 3, 4, 6, 7, 8, 9, 10, 11, and 12 as primary inputs in the scoring model. The information from the individual questions was consolidated in various combinations to obtain the evaluation factors shown in Table 4. Information from Questions 2, 3, and 4 was combined and identified as Factor A. The product of the scalar values from these three questions indicates the relative importance of a system in future Army aviation operations. Questions 6 through 12 each represent a specific system characteristic and are considered as individual factors (Factors B through H). The rationale for each of these factors is also described in Table 4. Answers in the questionnaire were converted to numerical scales in the scoring models. In addition, the components listed in the questionnaire for Factors B through H were rated individually. Rated component scores were added according to specified weights (Table B-2 in Appendix B) to derive scores for factors. Table B-1 in Appendix B explains the numerical conversion of information on scheduled years for introducing new aviation systems (Question 3), of estimates on extensiveness of system usage (Question 4), and of alphabetic ratings for degrees of differences (Questions 6 to 12).

2.3.2.2 Scoring Model Measures

Further considerations led to the development of ten measures of future Army aviation training needs related to behavioral research requirements. These measures are additive or multiplicative combinations of the basic factors. Table 5 summarizes the ten measures and Figure 1 is a block flow diagram of the scoring model development. The measure for overall importance $(A)(B+C)(D+E)(F)$ may be too strongly influenced by variations in the measure for skill and interaction change (F). If so, $(A)(B+C)(D+E)$ should be used as an overall measure of importance of the system in considering behavioral research needs, compared to scores of other systems.

2.4 PERSONNEL FACTORS

Training requirements involve not only the characteristics of the systems and the tasks to be performed, but also the characteristics of the

TABLE 3
QUESTIONS ASKED IN INTERVIEW SURVEY

-
1. What new systems will be in the U.S. Army aviation inventory for the period of 1985 to 2000?
 2. What are the probabilities that each of these new systems will be introduced into the Army inventory?
 3. What are the scheduled years for introducing each of these new aviation systems?
 4. How extensive will be the use of each of these new systems?
 5. What are the current systems, if any, to be replaced or supplemented by each of these systems?
 6. How much difference will there be between the new system and the current systems in terms of physical characteristics and what is the nature of the difference?
 7. What performance differences will there be between the new system and the current systems?
 8. In terms of cockpit crew operations, what are the differences between the new system and current systems?
 9. In terms of combat operations tasks, what are the differences between the new system and current systems?
 10. What are the differences in man-machine skill requirements between the new system and the current systems?
 11. What are the differences in crew interaction requirements between the new system and the current systems?
 12. In terms of training methods, how much difference will there be between the new system and the current systems?
-

TABLE 4
BASIC FACTORS IN THE SCORING MODEL

Factor	Rationale
A System Importance Q2 x Q3 x A4	If a system has zero importance, then training should be zero, therefore Factor A should be used as a multiplier.
B System Characteristics Q6 potential sum = 7.0	If systems characteristics are the <u>same</u> as current systems, but performance is <u>different</u> , or vice versa, value should be scored on basis of whichever is different, therefore add these two. If both characteristics <u>and</u> performance are same, no change in training is required, so sum of B + C should be multiplier.
C System Performance Q7 potential sum = 6.0	
D Crew Operations Q8 potential sum = 3.5	If crew operations are <u>same</u> as current systems, but combat operations are <u>different</u> , or vice versa, value should be scored on basis of whichever is different, therefore add these two. If <u>both</u> crew operations are same, no change in training is required, so sum of D + E should be multiplier.
E Combat Operations Q9 potential sum = 4.5	
F Skill Requirements Q10 potential sum = 4.0	If skill requirements are <u>same</u> as current systems, but crew interaction is different, or vice versa, value should be scored on basis of whichever is different, therefore add these two. If <u>both</u> skill requirements <u>and</u> crew interaction are same, no change in training is required, so sum of F + G should be multiplier.
G Crew Interaction Q11 potential sum = 2.0	
H Training Requirements Q12 potential sum = 7.3	This is a measure of overall impression of D + E and to a lesser degree of (B + C) x (D + E) and (B + C) x (D + E) x (F + G), or other multiplier combinations of the parenthetical groups, and therefore should be compared with the following on a normalized basis, to check correlation: Compare H with (B + C) (D + E) should correlate very closely, since H combines items listed in D + E (F + G) (B + C) x (F + G) other combination including (D + E) should not be significant if (D + E) in fact does correlate well with H, since no new information is added. If (D + E) does <u>not</u> correlate well with H, then causes for difference need to be resolved.

TABLE 5
MEASURES OF TRAINING NEEDS RELATED
TO BEHAVIORAL RESEARCH REQUIREMENTS

Measure	Factor	Indicator of Relative Importance
M1	A	System Importance
M2	B + C	System Change
M3	D + E	Operational Task Change
M4	F + G	Skill and Interaction Change
M5	A(B + C)	Importance of System Changes to Behavioral Research
M6	A(D + E)	Importance of Operational Task Changes to Behavioral Research
M7	AF	Importance of Skill Changes to Behavioral Research
M8	(B + C) (D + E)	Combined Effect of System and Operational Changes
M9	A(B + C) (D + E)	Importance of System and Operational Changes to Behavioral Research
M10	A(B + C) (D + E) (F)	Overall Importance

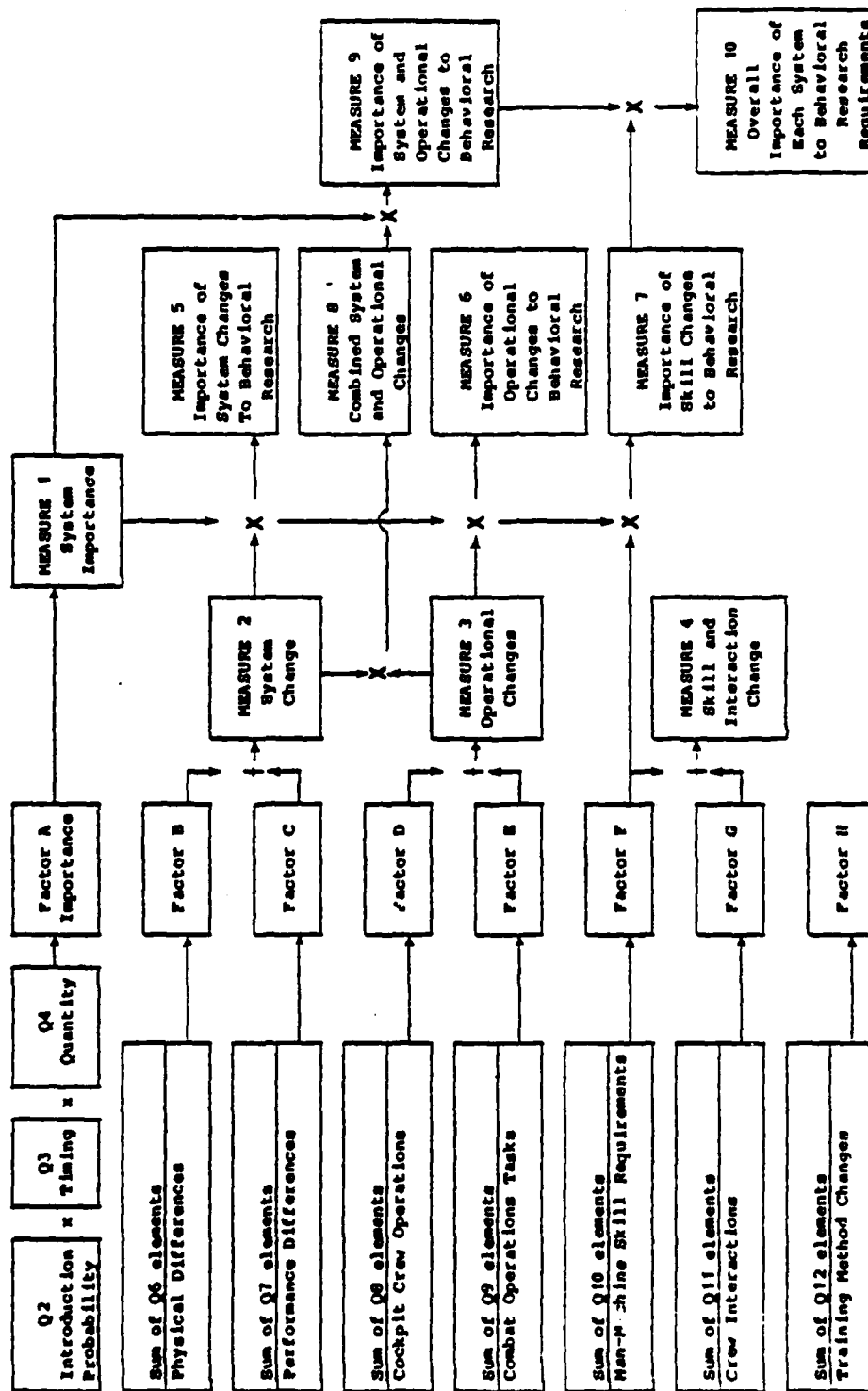


Figure 1. Scoring Model Flow Diagram.

personnel to be trained. The nature of the trainee population is largely determined by the number of trainees required relative to the level of Army personnel accessions. Therefore, some of the considerations which might affect the characteristics of the future trainee population were examined. The results of this examination are described in Section 8. Much additional work is needed to fully determine the probable characteristics of the trainee population. This would go far beyond the original scope of this study. However, even the limited amount of material contained in Section 8 on personnel availability provides some insights on this subject which are believed to be useful.

2.5 LITERATURE REVIEW

The collection of data through survey interviews and the analysis of that data through the scoring model indicated future changes in Army aviation and the relative importance of these changes to Army aviation training. However, to formulate a behavioral research plan, it was also necessary to be familiar with the present knowledge base for Army aviation training.

A literature review was conducted to determine the present knowledge base for Army aviation training. The first step was an on-line literature search of three data bases: Defense Technical Information Center (DTIC), National Technical Information Service (NTIS), and Educational Resources Information Center (ERIC). The second step was a review of the titles and abstracts of items identified through the on-line search. After this review, general categories of literature were created and items were categorized accordingly. Documents most relevant to issues in Army aviation training were obtained and reviewed. Based upon this review, refined categories of Army aviation training literature were created and relevant items were placed in the appropriate categories. Abstracts of the items in each category were reviewed to determine the present knowledge base.

The on-line literature searches of DTIC, NTIS, and ERIC were designed to identify relevant literature as broadly as possible. Besides such key identifiers as "Army Aviation Training," other identifiers such as "Flight Instrumentation" and "Flight Simulators" were used. The search concentrated on literature published between 1970 and 1980 because the material for this period was considered most relevant to the forecast of future research needs. This bibliography was placed in a computerized file, which is reproduced in Appendix E.

In order to identify areas where the literature about various training topics is insufficient or non-existent, an alternate categorization was created. This approach utilized the following structure:

1. PRETRAINING VARIABLES
 - 1.1 Performance Requirements
 - 1.1.1 Operations
 - 1.1.2 Instrument Flight
 - 1.2 Performance Measurement
 - 1.3 Trainee Selection

- 2. TRAINING TECHNIQUES AND TECHNOLOGY
 - 2.1 Adaptive Training and Computer Aided Instruction
 - 2.2 Simulation and Simulators
- 3. UNDERGRADUATE TRAINING
- 4. POST GRADUATE ISSUES
- 5. OTHER TRAINING RELATED LITERATURE

The primary use made of this literature was to provide background knowledge for the research and analysis reported in this study. The synopsis of this literature, and the references pertaining to each category (contained in Section 8), should be helpful to an understanding of the current state of knowledge in categories listed.

SECTION 3 SYSTEM AND SUBSYSTEM CHARACTERISTICS

Characteristics of five major helicopter systems and seven advanced subsystems were identified in the survey in terms of their training needs. Missions of future helicopter systems, the characteristics of future systems and subsystems, and the current systems and subsystems to be replaced or supplemented were discussed with the survey respondents. The probability of introduction, the number of units, and the date of introduction of each system/subsystem were estimated. Differences between a future system/subsystem and its current counterpart were explained for seven items: physical characteristics, system performance, crew operations, combat operation tasks, man-machine skills, crew interaction requirements, and training methods. The following information on each system or subsystem is based mainly on the information provided by the Army personnel during the interview survey.

3.1 ADVANCED SCOUT HELICOPTER (ASH)

The Advanced Scout Helicopter (ASH) was also identified by various respondents as the LHX-SCOUT 1990's, and was evaluated under the generic designation "Far-Term Scout Helicopter, System No. 1". This system will be able to perform its mission in a high threat environment in all weather conditions, including night-adverse weather conditions. The primary missions for the ASH will be target detection and designation for attack helicopters and field artillery, battlefield reconnaissance and screening, and battlefield management (C³M). The ASH will supplement or replace the Near-term Scout Helicopter.

The ASH is likely to be introduced in the early to mid 1990s. There is about 50 percent likelihood that specific concepts described here will be introduced. If the ASH is introduced operationally, about 1,000 aircraft will be procured.

Superficially, the ASH will appear similar to other helicopters. Main differences will be in the avionics suite. Extensive use of digital systems will be evident with fly-by-wire flight controls, integrated threat detection, and multiple CRT displays. The crew complement is not yet decided. Some survey respondents favor a single-seat aircraft. Helicopter performance will be enhanced, particularly in the areas of maneuverability, survivability, and crashworthiness. Pilot workload, in terms of basic flying tasks, will be greatly reduced. Target detection will be enhanced by a new generation of sensors, such as FLIR, millimeter wave radar, and advanced optical sights. Laser target designation will also be available.

The ASH's advanced navigation systems and displays will ease the pilot's basic flying task in both nap-of-the-earth (NOE) and instrument flying. The advanced target and threat detection capabilities and the battlefield management capabilities will be improved over the Near-term Scout. Target detection by one of a number of sensors and laser target designation will be new. Air-to-air combat against enemy helicopters will involve new flying tactics and tasks.

New skills required by ASH crews will include the ability to use multiple sensor displays with superimposed visual fields and to process a much greater amount of information. The decisions will be the same as today; the amount of information will be much greater. Basic flying skills will be less critical, although the all-weather capability may require much more "wet-instrument" flying experience (i.e., experience in actual instrument meteorological conditions) on the part of the pilots. Most flight maneuvers will be unchanged. Additional skills will be required for air-to-air combat maneuvers, and for target tracking with the mast-mounted sight (MMS) while remaining shielded behind terrain or trees.

3.2 SEMA-X

SEMA-X (Special Electronic Mission Aircraft) will replace or supplement OV-1, RU-21, and EH-1 aircraft in the 1990s. The primary mission of SEMA-X is reconnaissance, surveillance, and target acquisition and designation. There is 80 to 90 percent likelihood that this aircraft will be introduced. About 100 to 300 aircraft will be in the Army inventory.

Flight controls, instruments, and display systems on SEMA-X will be similar to those on Far-term Scout Helicopters. The aircraft will have either an inertial or a Doppler navigation system. Artificial intelligence electronic algorithms could enhance images and secure communication in the data link. Millimeter wave radar will be used extensively in the all-weather reconnaissance mission. SEMA-X will increase the variety of the crew's workload but decrease the complexity of work. The new aircraft will be more complex and will have more high speed capability than the aircraft it replaces.

Inertial and multiplex navigation systems will provide substantially more precise location and training capability. More on-board communication processing for real-time intelligence to the field commanders is expected. The aircraft will use a microwave landing system. The crew will have access to better target detection and laser designation capabilities to combat operation tasks.

SEMA-X will have more monitoring displays. The decision-making process and the memory function of crews will be aided by on-board computers. Thus, the crew skill requirement may increase, but the crew workload will decrease. Time aloft will be increased to minimize the number of aircraft required. Since it will be fatiguing to operate the SEMA-X, both crew members will be pilots.

3.3 BLACK HAWK

The primary mission of the Black Hawk helicopter is troop assault extraction and resupply of troops in combat. Other missions include aeromedical evacuation and combat service support activities. Black Hawk helicopters are in current use in Army aviation operations. Black Hawks are used together with UH-1 helicopters at a ratio of 15 Black Hawks for 23 UH-1's.

Future Black Hawks will weigh less, and will be more reliable with state-of-the-art improvements. They will have tilt rotors and will utilize

advanced blade concepts to make the helicopter more flexible. The flying workload of the Black Hawk will decrease as much as 50 percent. Improved small digital displays will be used in target detection. New sighting devices and laser ranging will increase weapon accuracy. Black Hawks will be equipped with a larger number of digital systems.

Basic flying functions will be the same, but characteristics will be different due to side arm stick control. Aircrew will use CRT, digital readouts, and automatic Instrument Flight Rules in instrument flying. Doppler radar will simplify navigation operations.

The Army Digital Avionic System (ADAS) will increase Black Hawk capability in target detection and target attack. SOTAS capability will facilitate command and control information processing and reconnaissance operations. Aircrews will use FLIR or IR sensors for target recognition.

3.4 ADVANCED ATTACK HELICOPTER (AH64)

The Advanced Attack Helicopter (AH64) is a highly mobile aerial weapon system capable of providing direct and indirect aerial fire in support of ground units in day, night, and marginal weather operations. In its primary mission as an attack helicopter, the AH64 will attack enemy tanks, other armored vehicles, troop formations, command posts, and forward logistic complexes. It will also engage in air cavalry operations attacking targets of opportunity.

The AH64 will enter service in the early to mid-1980s with several hundred aircraft being produced. Production and employment of this system is considered almost certain.

The most significant physical difference between the AH64 and present helicopters will be the displays--both pilot displays and copilot/gunner displays. The present night vision goggles will be replaced by multiple sensor (FLIR, LLTV, etc.) displays which will be presented head-up (HUD) or on a helmet mounted display. The gunner will have an advanced target acquisition and designation system to enhance weapon aiming. This target designation system will use a laser beam to identify the target. The AH64 will be much more agile, and will be engineered for greater survivability (including two engines) and crashworthiness. Weapon capability will be much greater than in previous attack helicopters, including a 30 mm gun, 2.75 inch rockets, and the Hellfire missile.

For AH64 cockpit crew operations, many of the basic tasks will be the same as in present-day attack helicopters; however, the character of the tasks will be changed as a result of the new sensor/display/computation systems. The major difference will be the need for the crew members to monitor the advanced systems and displays, particularly the digital systems. Fault isolation and carrying out alternative procedures will introduce major changes in crew member tasks.

The major man-machine skill that will be necessary for the AH64 crew will be the ability to use the novel displays, particularly the helmet-mounted displays or head-up displays with multiple images in the same visual field. The ability to monitor digital systems, diagnose system faults, and carry out alternate procedures will also be needed skills.

3.5 NEAR-TERM SCOUT HELICOPTER

The mission of the Near-term Scout Helicopter is to provide air-to-air protection for attack helicopters, support multiple aircraft operations, locate targets for attack helicopter strikes, suppress ground defenses, and provide ground commanders with battlefield update information. The crew complement for this helicopter has not been determined; therefore, specification of future training needs must include possibilities of either a single-pilot crew or a pilot-and-observer crew.

The Near-term Scout Helicopter is expected to be introduced around 1985 with an 80 percent likelihood of introduction. The number of units required is between 300 and 1,000.

Some of the features of the subsystems include a cathode ray tube display which provides automatic tracking, cueing and position updating, and air-to-air missile capability. The major subsystems include a laser system for target discrimination and ranging, a missile system which provides a fire-and-forget capability, a Low Light Level TV system (LLLTV) for night operation, a Forward Looking Infrared (FLIR) capability for weather and night visibility, a projected map display and Doppler navigation capability, a video recording system for reconnaissance, a Position Location Report (PLR) system, and improved communications and multi-function radius.

The sensors required for FLIR, LLLTV, visual, and laser systems are contained in a Mast Mounted Sight (MMS). Employment of this device facilitates helicopter operations from concealed locations behind trees, ridges, buildings, etc. which reduces enemy detection and exposure to ground fire.

Training programs are required for all these systems, as well as training in the tactics developed to exploit the capabilities of these systems. Some considerations in this regard include ground defense suppression, air-to-air combat, gunship coordination, relief of aircraft on station, night adverse weather operations, multi-aircraft operations, utilization of the Mast Mounted Sight, and Command and Control information for the battle commander.

3.6 ARMY DIGITAL AVIONIC SYSTEMS

Three generations of ADAS (Army Digital Avionic System) are planned to meet future Army aviation needs. The first generation includes IACS (Integrated Avionic Control System), AMD (Advanced Map Display), Doppler, NNPS (Night Navigation Pilot System), and ADTS/TH (Airborne Data Transfer System/Target Hand-off). The second generation involves EMMADS (Electronic Master Monitor Advisory Display), advanced audio systems, integrated multi-function display (e.g., FLIR, LLLTV), solid-state programmable multi-format display, and wire and wire-like optical detect system (CO₂). The third generation will integrate fire control, flight control, electronic warfare, and landing systems to achieve night and all-weather Nap-of-the-Earth capability. ADAS will replace all current corresponding systems. Time tables for introducing ADAS are 1986 to 1990, 1990 to 1995, and 1995 to 2000 for the first, second, and third generation, respectively. The quantities to be procured are expected to be in the thousands.

ADAS represents new technology and advanced state-of-the-art in aircraft instruments and displays. ADAS will have smaller panels but will be much easier to use. This subsystem will cut down the avionic workload and provide better information concerning flight safety characteristics. It will take some programming effort by the aircrew to operate ADAS.

ADAS displays are easier to read and provide more time for recognition, memory, decision-making tasks, and physical response. The degree of difference in crew interaction requirements will depend on who has displays and the number of redundant displays.

3.7 ADVANCED LANDING SYSTEM

As Army helicopter operations are extended further into adverse weather conditions, the need for an all-weather landing system will become evident. Such a system will be used by attack, scout, and supply helicopters to ensure continued operations at forward locations even during adverse weather conditions. Currently, it is not clear exactly what the system will be like. Two alternatives appear likely, however. One is a self-contained, zero-zero landing system that will allow the helicopters to operate independently of any ground-based navigational aids. Such a system will depend on the aircraft's navigation system for determining its location (Doppler, inertial, etc.). An alternative system would be development of the microwave landing system (MLS). This type of all-weather landing system would use ground-based signals and an airborne receiver to provide guidance, again down to zero-zero conditions.

Either system will require one set of airborne avionics for each helicopter equipped with the system (possibly two sets for heavy lift helicopters) or a total of several thousand shipsets. The MLS-based system will also require many (probably hundreds) of ground-based transmitters. It is likely that one or the other of these systems will be developed. The MLS system is virtually certain since most of its technology is "off-the-shelf." The probable introduction of this concept will be in the late 1980s or early 1990s.

Operationally, it is difficult to be precise about the use of such a system, since it is not yet defined. However, it is likely that the helicopter will fly a curved, descending, de-celerating path to a hover slightly above the point of intended landing. A vertical descent will follow until ground contact is made. The major problem involved in these types of operations will be the separation of all of the friendly helicopters in the area who are also using the same landing site. Some form of air traffic control, either traditional or novel, will be required to prevent the possibility of a mid-air collision. The second problem involves servicing or unloading the helicopters during adverse conditions. Ground operations will be equally hampered by low visibility.

The man-machine skills required to fly and land the helicopter in very poor conditions will be quite traditional, although at a higher level than the present one. Some additional training may be required to enable the pilots to visualize their positions continuously during the curved approach trajectories.

3.8 AIRCRAFT ROCKET SYSTEMS

An advanced aircraft mounted rocket system will be installed on Army attack helicopters. This system will replace existing launchers, rocket motors and certain warheads. The rocket system will include a new multiple purpose submunition, which has no present equivalent.

The multiple purpose submunition, lightweight launcher, and new rocket motor are virtual certainties with an estimated introduction in 1983. A smoke-screen warhead and an illumination warhead are considered probable additions to the inventory with anticipated IOCs of around 1985. Several thousand units are planned.

The advanced rockets will be more accurate and will have a 50 percent range improvement over existing weapons.

Crew tasks will be easier since the rockets are easier to aim than present equipment and the system will provide the crew members with range information, thus eliminating some decision-making tasks.

3.9 AIRCRAFT GUNS

New airborne automatic guns are proposed for installation on Army helicopters to replace existing 20 mm guns as used on the AH-1 Cobra.

Production of these new guns is considered highly probable, with an expected introduction in the late 1980s. Between 1000 and 3000 shipsets will be procured.

The new guns will differ from present weapons in the drive, feed system, and ammunition. The rounds will have greater range than present day armament.

The major change in combat operations involving the use of the new guns will be the inclusion of air-to-air combat against enemy helicopters. Air-to-ground operations will be similar to those in use today, except for greater range and standoff capability.

Crew members will require greater air-to-air tracking skills than today. They will need to process additional information during these air-to-air engagements.

3.10 FIRE CONTROL SUBSYSTEM

3.10.1 Mast-Mounted Sight (MMS)

The Mast-Mounted Sight (MMS) is a weapon-aiming device mounted above the helicopter rotor disk on a mast. This high location allows the helicopter's crew to sight targets and potential targets while the bulk of the aircraft remains shielded by terrain or other topographical features. An analogy with submarine periscopes is appropriate. The MMS will supplement conventional sights.

The MMS will probably be introduced in the mid-1980s with several thousand being procured. Its introduction is highly probable.

The MMS will be located atop the main rotor mast above the rotor disk. Several sighting modes may be developed-optical, television, FLIR, etc.

The physical appearance of the sight itself will depend on which type of sensor is employed. The sighting direction will be controlled by a crew member independently of the aircraft heading. The target image will appear on appropriate displays in the cockpit.

Significant differences from current operations with conventional sight locations will include requiring the pilot to hover more or less out of view of the target while maintaining MMS observation of the target and (particularly in one-man helicopters) slewing the sight to point at and track the target.

Pilots will have to be trained to hover in confined spaces while splitting their attention to keep the mast free from visual obstructions and (simultaneously in single crew aircraft) to control the sight. Depending on the display format chosen, the crew members may have to integrate several sensor images superimposed on a visual field. This use of multiple images may well lead to the spatial disorientation problems reported by pilots flying head up displays. If two-man crews are used, effective procedures and training in gunner/pilot communications and coordination will be necessary to allow the gunner to track the target while the pilot maneuvers the helicopter.

3.10.2 Advanced Night Vision Systems

Advanced night vision systems have been described by a number of respondents as being an integral part of several other systems. These new night vision systems would use a variety of sensors and display techniques to augment the crew members' direct vision during night and adverse weather operations. Several types of sensors have been described, including FLIR and millimeter wave radar. These systems would replace or supplement existing night vision goggles (NVGs).

The number of such systems is likely to be in the thousands of units, unless the cost restricts the numbers. While it is highly probable that an advance over present NVGs will develop, no estimate of a probability for specific systems can be made at this time, and a likely date of introduction cannot be estimated.

One of the major differences introduced by the new system(s) will be the mounting of the sensors on the aircraft coupled with an aircraft mounted display, instead of the helmet-mounting of the night vision goggles. The new systems will certainly have much better performance in terms of detecting targets, obstructions, wires, etc. than present NVGs.

No major differences in operations will be evident other than those that result from the increased system performance. However, this enhanced capability, coupled with evidence of substantial emphasis on night-time operations by the enemy, should markedly increase the proportion of time devoted to training for night operations.

If a HUD is used to display the images, the training problems that the Air Force and NASA found related to pilot perception of information from two distinct visual images in the same field will result. These studies show some difficulty in perceiving one field while examining the other; however, this difficulty may be overcome through training. References 5 through 23 provide information on this subject.

3.11 ADVANCED DIGITAL OPTICAL CONTROL SYSTEM (ADOCS)

The Advanced Digital Optical Control System (ADOCS) replaces the current flight control system which depends upon hydraulic lines, connectors, and electronic and mechanical controls. The ADOCS does away with most of these components. This system utilizes a signal processor which responds to sensor information and pilot input for control activation. ADOCS will replace the current conventional flight control system.

It is almost certain that helicopter control systems based on the ADOCS approach will be dominant in the future Army helicopter inventory. The time table for ADOCS introduction is 1985 for the Black Hawk helicopter.

The physical characteristics of ADOCS represent a vast improvement over dual redundant mechanical systems now employed. A large part of the improvement is due to employment of sensor information. Cathode Ray Tubes (CRT) will provide sensor information and display. The ADOCS will include control capabilities required for air-to-air combat. The system should facilitate night operations, reduce workloads, and provide faster target acquisition and fault diagnosis. An integrated capability for communication and navigation will be possible. Flight control laws will be solved in a more precise manner. Redundancy and reliability will improve flying safety. Many of the time-consuming tasks usually done by the pilot will be accomplished automatically. Weight reduction and improved weapon accuracy are likely by-products of this technology. The control system and automatic features of ADOCS will allow the pilot more time and freedom to look for targets.

The operational tasks of target detection, attack, weapon firing, air-to-air combat, multiple aircraft operation, reconnaissance and command and control processing will be much easier using the ADOCS because of the information processing and advanced capabilities provided.

Training differences which are peculiar to the ADOCS involve effective monitoring of displays, tracking outside of aircraft, memory, recognition, and decision making. This is primarily due to the method of presentation and the amount of information provided to the pilot. Reduction of the crew workload, and increased pilot opportunities for "head-out-of-cockpit" flying will permit better spotting of targets and easier detection of threats. Training will be easier for basic, instrument, and nap-of-the-earth flying, because the flight control system and associated sensors will make the aircraft much easier to handle, and control coordination will not be as critical.

ADOCS provides some totally new capabilities. The helicopters can be positioned more accurately, overall flying will be easier, combat tasks will be easier to accomplish, and operational performance will be greatly improved.

3.12 INTEGRATED DIGITAL SYSTEMS VALIDATION (IDSV)

Integrated Digital Systems Validation is a concept that could become a part of the Army Digital Aircraft System (ADAS). In the IDSV concept, two CRTs would replace the dials, knobs, etc. of current display systems. This system should integrate the currently separate controls and displays.

The introduction of this concept into the Army inventory is not certain. If the concept is introduced, it would ultimately affect most Army

helicopters. The anticipated introduction date is somewhere in the 1987 to 1990 period if developed concurrently with the ADAS. Otherwise, it could be somewhat later.

The physical characteristics of the concept allow most of the aircraft functions to be tied into two CRTs with a head-up display. An integrated flight control system with a side arm controller will be utilized. Command and control information will be displayed on the CRT, as well as map display. Integrated systems utilizing a CRT will address the visibility, weapon guidance, guns, rocket, and threat detection requirements. Performance differences will be noted in such areas as better night maneuverability, flight stability, control responsiveness, lesser workload, and better safety of flight characteristics. System complexity will be substantially different due to modular make up and system self-diagnosis. Target detection capabilities will be enhanced due to automation and the ability of the pilot to keep his head out of the cockpit. Troop and cargo capabilities will be greater due to the estimated 400 pound reduction in wiring and structure which the IDSV will provide.

Cockpit crew operations will be substantially different, the aircraft will be easier to fly, instrument flying will be easier, and nap-of-the-earth flying will be enhanced by use of sensor displays on the CRT. The navigation system will feature computer graphic map displays. Doppler radar will be used for wire detection as well as navigation. Radio functions will be push button controlled for all frequencies and will be incorporated in the Integrated Avionics Control System (IACS).

Combat operational tasks involving target detection, target attack, and weapon aiming and firing will be radically different because of cueing features of the system, and the pilot's ability to keep his head out of the cockpit. Multiple aircraft operations, reconnaissance, and command and control information processing will be substantially different. They will be easier to accomplish, automated information processing will be employed, and the pilot can spend more time looking outside the aircraft. The inertial or Doppler navigation system may facilitate automatic control of aircraft position and also automatic notification of location to other aircraft.

The man-machine interface will be substantially different in the areas of display monitoring, tracking, recognition, memory, decision-making and physical responses. Employment of the IDSV concept makes these tasks easier and provides more freedom to the pilot to make decisions not previously possible. The pilot will be relieved of routine decision-making, decision-making can be raised to higher order decisions, tracking will be done by the system, workload will be reduced, and less physical strength will be required.

If a one-man crew is employed, all crew interactions would be eliminated; if not, crew interactions would be substantially different in most cases. Verbal and non-verbal exchanges would be reduced by switching images from one display to another or by cueing to the display. Automation would reduce requirements for physical coordination in concurrent activities such as weapons aiming and flying.

The impact of IDSV upon training methods will be radically different in areas of target detection, target attack, weapon firing, air-to-air and air-

to-ground combat maneuvers, cargo operations and attack across the Forward Edge of the Battle Area (FEBA). This stems from the fact that the skill levels required can be acquired in much less time, and system automation reduces the need to teach many skills previously carried out manually. Substantial differences will be experienced in the areas of basic flying, instrument flying, nap-of-the-earth flying, navigation, communications reconnaissance, command and control, and rescue operations. This is due to the changed characteristics of the flight control system, the automation of many tasks, and the elimination of some skills requirements, such as the lower level physical tasks involving flying skill coordination. Higher level orders of decision-making will increase. This will be a by-product of better control systems, simplified cockpits, elimination of knobs and dials, and the use of automated equipment.

SECTION 4 SURVEY RESULTS

The survey instrument described in Section 2.2 was the method used to obtain information about the characteristics of future Army aviation systems and subsystems. The use of the survey instrument to structure the interviews made it possible to identify the characteristics which were most likely to require changes in training procedures, which in turn would need to be supported by behavioral research. All of the information gathered in the survey is reported in Appendix A.

The principal findings of the survey are synopsized in the following paragraphs. These are the items which may be expected to have the greatest impact upon training requirements and behavioral research needs.

4.1 SURVEY COMMENTS APPLICABLE TO ALL SYSTEMS

The phased introduction of successively more advanced systems will be preceded by the introduction of many elements of these systems, through modification of current Army aviation systems. Therefore, changes in training requirements will be gradual and may be introduced in an incremental manner. It does not appear that a radical overall impact will occur at any point. However, at the end of this decade, a look backward will reveal changes in almost every aspect of training.

The automation of many tasks will shift crew responsibilities and activities strongly away from current manual skills and procedures toward systems management and decision choices. There was almost universal agreement in the responses that the crew workload will be diminished in terms of manual operations, but will be increased greatly in terms of additional decisions. The greater performance and improved effectiveness of the new systems will be rapidly exploited to extend operational capabilities. Therefore, crew members will continue to be required to perform near the limits of human capabilities. In terms of the behavioral research needs, the most important point is that these limits will be in different areas than the limits approached in present systems.

The trend toward cathode ray tube (CRT) displays and other electronic displays will remove current instrument-imposed constraints on data presentation. For example, dial displays, previously dictated by clock-type mechanisms, will be replaced by alpha-numeric information. More importantly, multiple single instrument displays, which clutter the cockpit and demand constant scanning by the crew, will be replaced by selected information on the CRT's. The information presented at any time will be limited to that which the crew requires, or that which is automatically brought up to alert the crew to take necessary actions.

4.2 SURVEY COMMENTS APPLICABLE TO SUBSYSTEMS

The mast-mounted sight (MMS), by bringing helicopter operations even closer to the terrain and lower than surrounding objects, will increase the hazards of nap-of-the-earth (NOE) flight. The reduced vulnerability to enemy

action will be bought with some increase in collision hazard. Reduced use of "pop-up" maneuvers for target location will tend to substitute visual perception requirements (using the MMS) for flying skills associated with the "pop-up" maneuver.

Millimeter wave radar, LLLTV, forward-looking infrared (FLIR) target detection, acoustic sensors, and laser designation of targets will enhance night and all-weather combat capabilities. This, coupled with the increasing requirement for night operations, will emphasize the need for concentration on training relevant to night and all-weather combat. Training on the displays associated with these targeting technologies should be a very important part of future training syllabi. Because the inputs to the displays are electronic, simulation is essentially easy, cheap, and highly adaptable to part-task training.

The survey responses concerning advanced navigation equipment were limited to moving map displays and digital information presentations. Concern was expressed about the problems of navigation in NOE flight. However, the three aspects of this problem; i.e., navigation equipment, navigation requirements, and crew capabilities, were not effectively integrated in the discussions. It appears that navigation during NOE operations under combat conditions at night and in adverse weather will severely strain the capabilities of both equipment and crew. If this problem is as great as anticipated, both selection of pilots based on aptitude for navigation and intensive training will be required. As deficiencies in navigational capabilities are revealed by realistic combat training and simulation, it is likely that new navigational equipment will be required. Some respondents noted that inertial navigation equipment has been suggested as one means for solution of navigational problems. However, other respondents considered them to be too heavy for inclusion in helicopters. Trends towards simpler and lighter inertial navigation equipment might alleviate this objection. One solution to the navigation problem is the Global Positioning System (GPS), using satellites, but it was viewed unfavorably by some respondents because of the potential vulnerability of the satellites to enemy action. The necessity of an alternate navigation method was considered to impose additional weight and training burdens. Strong emphasis was therefore placed on the need for self-contained navigation equipment.

Electro-optical, multiplex, digital, fly-by-wire, side-arm stick flight controls as typified by the ADOCS (Advanced Digital Optical Control System) and IDSV (Integrated Digital Systems Validation) will materially reduce the manual coordination skills required for helicopter piloting. Much of this technology is identified under the program title ADAS (Advanced Digital Avionics Systems) which encompasses three generations of development. Training syllabi should reflect this advance by reducing the time allocated to flying skills, as compared to time allocated for other training needs. Reducing the flight control portion of pilot workload may permit single person cockpit operation in scout helicopters. Single crew helicopters would be less vulnerable because of smaller size and signature, would reduce personnel casualties, and would lower costs. Separate training for the second crew member would of course be eliminated.

Communication, command, and control using secure digital data links to replace voice communications will involve completely new patterns of behavior

in transmission of information and responses. This will be contrary to almost all prior individual experience, since from very early childhood each person's primary communication mode is by voice. Therefore, substantial retraining will be necessary for accommodation to the digital data mode.

Computer storage and processing of information will relieve the crew of much currently required activity. The automation of this activity will bypass human limitations, thus increasing the level of decision-making by the crew. At the same time, many actions that currently require crew decisions may be taken over effectively by the computer.

The Pilot Night Vision System (PNVS) and the Target Acquisition and Designation Systems (TADS), along with Head Up Displays (HUD), will provide cues for flying and combat activities which differ substantially from current customary visual cues. These differences will require specific consideration in training, particularly when the training is being conducted by instructor pilots who are more accustomed to older technologies. Also, the images in many of the displays will be dissimilar to the normal visual images of the terrain, targets, and threats. Therefore, training to recognize these unfamiliar images will be required.

Several respondents noted that pilot coordination of the information obtained from helmet mounted sights, head-up displays and CRT presentations, along with external imagery, may introduce some problems. Disorientation in transferring from one viewing mode to another is a known hazard. Also, image slewing on displays which differs from aircraft motion may pose problems for designers and may require special attention in training.

4.3 SURVEY COMMENTS ON CREW OPERATIONS

The responses to questions concerning crew interaction requirements were somewhat limited. However, there was an expression of the need for two-man crews to work very closely as a team. One view is that these teams need to train together, work together, and live together, so that their responses to each other's actions and words are automatic and anticipatory. Other comments mentioned the need for very good rapport, and the interactive cueing possibilities offered by the new display forms.

A need was expressed for upgrading the selection and training of observers. This was extended by the suggestion that the occupants of both seats in a two-men helicopter should be cross-trained and fully qualified for both jobs.

A question was raised concerning the possible advantages of having special crews for night operations. This would entail crew selection based on aptitude for night flying, followed by exclusive concentration on night operations during training.

4.4 SURVEY COMMENTS ON SPECIAL TASKS

The SEMA-X (Special Electronic Mission Aircraft) is the only proposed Army aviation system which will introduce significantly different flying characteristics. Assuming that a tilt-rotor configuration is selected for this system, appropriate training will be required for pilot adaptation to the

special characteristics of such a configuration. Transition from hover to forward flight and the reverse will be the new skills required. Basic flying techniques for this transition should be learned easily. Training in the effective use of this capability for evasive maneuvers following threat detection will require more training.

Mention of special jobs requiring training included wire and cable cutting, and tasks associated with ground coordinate targeting. Questionnaire No. 9 in Appendix A, dealing with the AH64 Attack Helicopter, deserves special attention because it describes so many of the training-related characteristics which will be typical of future systems.

4.5 SURVEY COMMENTS ON MAJOR COMBAT TRAINING ISSUES

The absence of a realistic environment for conducting war games was noted as a problem. This lack affects both the training itself and also the determination of training needs. Combat ranges which would provide a variety of typical environments for testing equipment and training effectiveness were cited as a major need for Army aviation.

Air-to-air combat looms as a very large problem in the future. The presence of armed enemy helicopters has been identified as a unique and perhaps a far more serious threat than the fighter "aircraft." [24] In spite of this statement, there is no current doctrine for the helicopter air-to-air combat role. No combat experience exists to supply a foundation for such doctrine. The survey responses did not identify any simulation of helicopter air-to-air combat as a basis for development of doctrine and tactics. Since equipment such as air-to-air missiles and other weaponry is being provided, it appears that a structure of doctrine, tactics, and training for air-to-air combat is vitally needed. In this respect the words of General H. H. Arnold have particular significance. In 1945, he said, "Any air force which does not keep its doctrine ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security." It is clear that Army aviation cannot wait for a war to provide the experience upon which to develop air-to-air combat capabilities. Combat simulation must be conducted to test tactical concepts. The experience thus gained should provide the basis for development of doctrine. Then training can be initiated. This item is last in this synopsis because so little could be said about it by the survey respondents. However, it is possibly the most important of all the training needs of the future.

SECTION 5

SCORING MODEL RESULTS

The scoring model analyses synthesize information from the survey interviews provided by Army personnel who expressed opinions about various parts of the entire spectrum of future Army aviation systems and subsystems. Differences among the responses were found in a small number of questionnaire answers. These differences were resolved after review of additional information and deliberations among the research team members. The resolutions of these differences are described in Section 5.1.

The evaluations of the basic factors and the scoring model analysis for the complete systems were expected to have different implications for training needs than the similar analyses of the subsystems. Therefore, aviation systems and subsystems were evaluated separately. The scoring model analysis indicated the relative importance to training and behavioral research of projected changes both in the Army aviation force as a whole, and in individual helicopter systems. Similar analytical information was available both for individual subsystems and for the total of those subsystems.

5.1 MODIFICATIONS OF QUESTIONNAIRE ANSWERS

Several significant differences occurred in the questionnaire answers. Compromises and adjustments to these answers were made to facilitate a meaningful scoring model analysis. One type of difference came from interview respondents' differing assumptions about the configuration of future systems or subsystems. To provide a common base for evaluation, responses were adjusted to reflect the most probable system configuration.

Another type of difference apparently came from dissimilar views on certain operational characteristics. In such situations, adjustment was made to conform with the opinion of the individual who had better understanding of the subject. For instance, a pilot's opinion was followed in the case of substantially dissimilar views concerning crew operation activities.

Certain differences were easily corrected after reviewing additional information. For instance, differing opinions on the extensiveness of usage for an aviation system or subsystem were adjusted on the basis of published procurement plans.

Some additional items provided by interview respondents were excluded from the scoring, although the valuable content of these items was retained for other purposes. The interviewee may have added any number of such additional items in answering questions for a given system or subsystem. This variation in the number of additional items could produce a very substantial difference in scores which would not present a true picture in the scoring model analysis.

Descriptions and justifications of all adjustments of questionnaire answers are included in Appendix C, Volume II.

5.2 SCORING MODEL MEASURES

Results of the scoring model analysis are summarized in Tables 6 and 7. Complete systems and subsystems were analyzed separately. Scores by individual interviewee and weighted average scores for those systems and subsystems that had more than one respondent are included in the tables. The weighted average scores were used for the evaluation. The columns of Tables 6 and 7 are derived from questions asked in the survey questionnaire described in Table 3, as defined in Section 2.3.2. A high score means a high degree of difference between a current system and the future system which will replace or supplement the current system.

The following examples are offered to assist understanding of the construction, use, and content of these two tables. The first line of Table 6 describes the scoring from Questionnaire No. 2 for the Far-term Scout Helicopter (System No. 1). The entry "0.50" under "Q2" indicates that the respondent thought that the probability that this system would enter the Army inventory was 50 percent. The entry "0.40" under "Q3" indicates the respondent's opinion that this system would not be introduced until after 1995. The entry "0.60" under "Q4" indicates an opinion that the total number of these systems in the inventory would be more than 300 but less than 1000. The entry "0.12" for M1 is the multiple of the previous three entries, and is a rating of the system importance of the Far Term Scout in terms of these three questions.

The entries under "Q6" and "Q7" are the sums of the physical and performance differences, respectively, between the Far Term Scout and the current systems which it will replace or supplement. (The elements of these sums are the weighted scores of the degrees of difference of the components of the system, as described in Appendix B, Volume II.) The high scores indicate substantial differences between the Far Term Scout and current equivalent systems in terms of physical and performance characteristics. The entry "6.65" under "M2" is the sum of the "Q6" and "Q7" entries, and indicates the respondent's opinion of the degree of change incorporated in the Far Term Scout. The entry "0.80" under "M5" is the multiple of the "M1" and "M2" entries, and represents the combined importance of the system and extent of change, relative to training and behavioral research requirements.

"Q8" and "Q9" entries represent cockpit crew operations and combat operations task differences, respectively. The scores are sums developed as described in Appendix B. The relatively high scores indicate that substantial task changes are anticipated in the introduction of this system. Entry "2.96" under "M3" is the sum of the "Q8" and "Q9" entries. Multiplication by "M1" provides the "M6" entry of "0.36", which is a measure of the combination of system importance and degree of task change, in relation to training and behavioral research needs.

"Q10" and "Q11" similarly represent evaluations of man-machine skill level differences and crew interaction differences. "M4" is the sum of these, and the relatively high score indicates the respondent's opinion that the Far Term Scout will differ substantially from current systems in these two respects. "Q10", multiplied by "M1", gives the "0.20" entry under "M7", which is a measure of training and behavioral research needs in terms of skill changes combined with system importance. ("Q11" is omitted in this calculation because of the wide differences in respondent opinions).

TABLE 6
RESULTS OF SCORING MODEL MEASURES FOR AVIATION SYSTEMS

MEASURE VERSUS SYSTEM																					
QSN#	SVSB	Q2	Q3	Q4	M1	Q6	Q7	M2	M5	Q8	Q9	M3	M4	Q10	Q11	M4	M7	M8	M9	M10	Q12
2	1	0.50	0.40	0.40	0.12	3.28	3.37	4.45	0.80	0.44	2.30	2.94	0.34	1.45	0.30	1.95	0.20	19.48	2.34	3.90	3.38
3	1	0.30	0.40	0.40	0.11	4.78	3.30	8.08	0.87	0.83	3.50	4.35	0.47	1.04	0.00	1.04	0.11	35.15	3.80	3.95	4.24
8	1	0.40	0.40	0.80	0.29	5.29	3.44	8.75	2.52	1.14	2.77	3.93	1.13	1.35	0.00	1.35	0.39	34.39	9.90	13.37	3.36
AVE	1	0.47	0.53	0.67	0.17	4.45	3.38	7.83	1.30	0.89	2.84	3.75	0.42	1.35	0.10	1.45	0.22	29.32	4.87	6.55	
2	2	0.90	0.40	0.40	0.14	3.40	3.30	4.70	0.96	0.35	0.70	1.05	0.15	1.10	0.00	1.10	0.14	7.04	1.01	1.11	1.05
8	2	0.80	0.40	0.40	0.19	3.34	1.77	5.13	0.98	0.42	0.84	1.48	0.28	0.94	0.12	1.08	0.18	7.59	1.46	1.40	0.38
AVE	2	0.85	0.50	0.40	0.17	3.38	2.53	5.91	1.01	0.49	0.78	1.27	0.22	1.03	0.06	1.09	0.18	7.48	1.27	1.31	
4	3	1.00	1.00	0.80	0.80	2.45	2.17	4.42	3.70	0.45	1.20	1.85	1.48	0.54	0.30	0.84	0.43	8.55	6.84	3.69	1.85
3	3	1.00	1.00	0.80	0.80	2.45	2.17	4.42	3.70	0.45	1.20	1.85	1.48	0.54	0.30	0.84	0.43	8.55	6.84	3.69	
7	4	0.80	0.90	0.60	0.43	1.89	2.03	3.92	1.69	0.50	0.71	1.21	0.32	1.30	0.00	1.30	0.54	4.74	2.05	2.46	0.65
9	4	0.80	0.90	0.60	0.43	2.39	2.14	5.55	2.40	0.49	1.22	1.90	0.82	1.75	0.32	2.07	0.74	10.55	4.56	7.97	2.08
AVE	4	0.80	0.90	0.60	0.43	2.14	2.40	4.74	2.05	0.59	0.97	1.56	0.67	1.53	0.16	1.69	0.44	7.36	3.18	4.85	
1	5	0.85	0.90	0.60	0.46	2.34	1.44	4.00	1.84	0.35	2.59	2.94	1.35	1.00	0.14	1.14	0.44	11.76	5.40	5.40	0.41
3	5	0.80	0.90	0.60	0.43	1.83	0.94	2.79	1.21	0.10	3.00	3.10	1.34	1.29	0.05	1.34	0.54	8.45	3.74	4.82	2.72
AVE	5	0.83	0.90	0.60	0.45	2.09	1.31	3.40	1.51	0.23	2.80	3.02	1.35	1.14	0.10	1.24	0.51	10.25	4.57	5.23	

- (a) Sys #1 Far-term Scout helicopter
2 SEMA-X
3 Black Hawk
4 Advanced Attack helicopter
5 Near-term Scout helicopter
- (b) Q.2 to Q.12 indicate question number in the survey questionnaire
- (c) M1--System importance
M2--System change
M3--Operational task change
M4--Skill and interaction change
M5--System changes and behavioral research
M6--Operational task change and behavioral research
M7--Skill change and behavioral research
M8--System and operational change
M9--System and operational change to behavioral research
M10--Overall importance

TABLE 7
RESULTS OF SCORING MODEL MEASURES FOR AVIATION SUBSYSTEMS

QSN#	SYS#	MEASURE VERSUS SYSTEM										M9	M10	Q12
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10			
6	11	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.34
AVE1	11	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.34
6	12	0.70	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10
AVE1	12	0.70	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10
5	13	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.06
AVE1	13	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.06
5	14	0.40	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.03
AVE1	14	0.40	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.03
1	15	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.25
5	15	0.70	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.00
AVE1	15	0.70	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.00
10	16	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.85
AVE1	16	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.85
11	17	0.40	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	5.45
AVE1	17	0.40	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	5.45

- (a) Sys #11 ADAS
12 Landing system
13 A/C Rocket
14 A/C Guns
15 Fire control
16 ADOCS
17 IDSV
- (b) Q.2 to Q.12 indicates question number in the survey questionnaire
- (c) M1--System importance
M2--System change
M3--Operational task change
M4--Skill and interaction change
M5--System changes and behavioral research
M6--Operational task change and behavioral research
M7--Skill change and behavioral research
M8--System and operational change
M9--System and operational change to behavioral research
M10--Overall importance

The entry in column "M8" goes back to "M2" and "M3", which are multiplied to give a measure combining system changes with operational task changes. "M8" times "M1" produces the "M9" entry of "2.36". This measure includes the effects of system importance relative to training and behavioral research needs. "M10" includes the influence of "Q10" as a multiplier, and "Q12" is the respondent's view of the overall difference in training methods between the new system and current systems.

The second line of Table 6 contains the scores from Questionnaire No. 3, which was also for System No. 1, the Far-term Scout Helicopter. The lines labeled "AVE" represent the averages of the questionnaires for each system. Only one questionnaire was obtained for the Black Hawk, so that the "average" is only a restatement of that questionnaire. The rank ordering of five systems using the scoring model is consistent with the ranking from the respondents' overall view, although the differences in absolute values are substantial. Because the sample size is small and the opinions of the respondents differ considerably, the numbers in the scoring model are of more significance in highlighting areas of greatest importance in training requirements than in indicating precise differences in importance.

Table 7 for the subsystems may be read in the same manner as Table 6.

5.3 ANALYSIS OF SCORES FOR SYSTEMS

The scoring model analysis of all the aircraft showed that in relation to training needs, the Far-term Scout Helicopter has the highest overall score (Column M10 in Table 6). The Near-term Scout Helicopter ranked second, the Advanced Attack Helicopter third, Black Hawk fourth, and SEMA-X last in the overall importance score. Scores on individual factors and measures provide additional insights. The results of the analysis of training needs for the five aviation systems are discussed in the following paragraphs and are synopsized in Table 8.












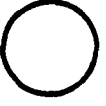













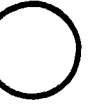









5.3.1 Far-Term Scout Helicopter (System No. 1)

The Far-term Scout Helicopter has the highest score on overall importance (M10). It also ranks high in system change (M2), operational task change (M3), skill and interaction change (M4), and combined effect of system and operational changes (M8). System change and operational task change are the principal reasons for the highest score in overall importance (M10). This helicopter had the lowest score on system importance (M1) due to the lower probability and the late date (in the late 1990s) for adding it to the Army inventory. Consequently, the system had low rankings on the combined measures, which included this measure along with system change, operational task change, and skill changes, all in relation to behavioral research needs. The system scored medium on M9, importance of system and operational changes to behavioral research. Nevertheless, the scoring model analysis recognized the overall importance of the Far-term Scout Helicopter as related to training needs and behavioral changes despite the lower probability and lateness of entry into the Army inventory.

5.3.2 Near-Term Scout Helicopter (System No. 5)

The Near-term Scout Helicopter ranked second in overall importance. It also registered second place in system importance, operational

TABLE 8
SYNOPSIS OF SCORING MODEL RANKINGS FOR AVIATION SYSTEMS

System Number	System Designation	System Importance	System Change	Operational Task Change	Skill & Interaction Change	System & Operational Change	Overall Importance to Behavioral Research
		M1	M2	M3	M4	M8	M10
1	Far-term Scout						
2	SEMA-X						
3	Black Hawk						
4	Advanced Attack Helicopter						
5	Near-term Scout						
							
		Highest	High	Average	Low	Lowest	

task change, importance of operational task change to behavioral research, importance of skill change to behavioral research, combined effect of system and operational changes, and importance of system and operational changes to behavioral research. System change in the Near-term Scout Helicopter was the least among five systems. However, the high score on operational task change produced high scores when this measure was combined with other measures. Crew operation and combat operation factors were the main forces behind the Near-term Scout Helicopter's second place in overall importance.

5.3.3 Advanced Attack Helicopter (System No. 4)

The Advanced Attack Helicopter was third in overall importance. It had the highest scores in skill and interaction change, and the importance of skill change to behavioral research. The scoring model analysis indicated this system ranked second in importance of system changes to behavioral research. System importance, system changes, operational task changes, and the importance of operational task changes to behavioral research in the Advanced Attack Helicopter were considered medium among the systems. Medium scores in system importance, system change, and operational task changes produced a medium overall score for the Advanced Attack Helicopter. The combined effect of system and operational change and its importance to behavioral research was considered low among systems.

5.3.4 Black Hawk Helicopter (System No. 3)

The Black Hawk Helicopter ranked fourth on overall importance. However, Black Hawk had the highest score on system importance because it is a current system with a large quantity in the Army aviation force. This highest score in turn generated the highest scores on the importance of system changes to behavioral research, the importance of operation task changes to behavioral research, and the importance of system and operational changes to behavioral research. The highest score on system importance alone was not enough to counter low scores on system change, operational task change, and the combined effect of system and operational changes. The scoring model analysis also showed that Black Hawk had the least difference in skill and interaction change among the five systems. Low scores on system change, operational task change, and skill change gave Black Hawk a low score on overall importance despite Black Hawk's highest score on system importance.

5.3.5 SEMA-X Aircraft (System No. 2)

The SEMA-X Aircraft was last in overall importance. This system consistently received low scores and ranked fourth or fifth in all but one measure used in the analysis. It had a high degree of system changes. Also, system changes in terms of system characteristics and system performance were considered greater than Black Hawk, Advanced Attack Helicopter, and Near-Term Scout Helicopter. However, low scores on system importance and operational task change kept SEMA-X in last place on overall importance.

5.4 ANALYSIS OF SCORES FOR SUBSYSTEMS

The seven aviation subsystems were examined in a separate scoring model analysis. The results are those presented previously in Table 6, which is synopsized in Table 9. These results are discussed in the following paragraphs.

TABLE 9
SYNOPSIS OF SCORING MODEL RANKINGS FOR AVIATION SUBSYSTEMS

System Number	System Designation	System Importance	System Change	Operational Task Change	Skill & Interaction Change	System & Operational Change	Overall Importance to Behavioral Research
		M1	M2	M3	M4	M8	M10
11	ADAS						
12	Landing System						
13	Aircraft Rockets						
14	Aircraft Guns						
15	Fire Control						
16	ADOCs						
17	IDSV						



5.4.1 Integrated Digital Systems Validation (IDSV)
(Subsystem No. 17)

IDSV had the highest score on overall importance. This subsystem also ranked highest in system change, operational task change, and skill and interaction change measures. These measures in turn enabled IDSV to rank first or second on the importance of skill changes to behavioral research, the combined effect of system and operational changes, and the importance of system and operational changes to behavioral research. IDSV's high scores on system change, operational task change, and skill change gave it the highest ranking on overall importance despite its low score in system importance.

5.4.2 Army Digital Avionic System (ADAS)
(Subsystem No. 11)

ADAS ranked second on overall importance. System change and system importance of ADAS were considered medium. Operational task change and skill change were the main measures which put ADAS high in overall importance. This subsystem also had the highest score on the importance of skill change to behavioral research.

5.4.3 Advanced Digital Optical Control System (ADOCS)
(Subsystem No. 16)

ADOCS placed third in overall importance. It had the highest score on system importance because of its high probability and the expected early inclusion of this subsystem in Army aviation operations. ADOCS also scored high on system change. Scores on operational task change and skill change on ADOCS were moderate among the seven subsystems. Operational task change and skill change determined ADOCS's ranking in overall importance. The combined effect of system change and operational task change, and the importance of system change and operational task change to behavioral research on ADOCS were medium among subsystems.

5.4.4 Fire Control Subsystem (Subsystem No. 15)

The Fire Control Subsystem described in Section 3.10 ranked fourth in overall importance. It had a moderate score for system change and operational task change. Skill change was less compared to other subsystems. The combined effect of system and operational changes, and the importance of system and operational task changes to behavioral research were also moderate in this subsystem.

5.4.5 Aircraft Gun Subsystem (Subsystem No. 14)

The Aircraft Gun Subsystem ranked fifth in overall importance. It scored low in system change and operational task change, and medium in skill change and system importance. Furthermore, the importance of system and operational task changes to behavioral research was low in the Aircraft Gun Subsystem.

5.4.6 Aircraft Rocket Subsystem (Subsystem No. 13)

The Aircraft Rocket Subsystem tied the landing subsystem for last place in overall importance. This subsystem ranked second in system

importance because of the high probability, the early introduction, and the large quantities involved. However, scores on system change, operational task change, and skill change were rather low so that a high score on system importance was not enough to make this subsystem significant in the overall rating.

5.4.7 Landing Subsystem (Subsystem No. 12)

This subsystem ranked in last place in overall importance. It was consistently low in scores on all evaluation measures.

SECTION 6
SYSTEM ELEMENTS WHICH WILL REQUIRE TRAINING
DIFFERENT FROM CURRENT PRACTICE OR ENTIRELY NEW TRAINING

The scoring model analysis pointed out the relative overall importance of the various systems and subsystems planned to meet future Army aviation needs. It also indicated the relative importance of seven basic factors relevant to training differences between current and future systems/subsystems. Each of the factor scores is actually composed of interview responses to the several parts of each question. The factor score is thus a summation of the answers to each part of the question which is the basis for the factor. These parts of each question are identified as "elements" in the discussion which follows. The "elements" differ from question to question, and include system components, characteristics, and operating functions. A highly structured, hierarchical taxonomy was not considered desirable in the questionnaire, since it was intended to elicit a wide range of responses concerning possible changes which might affect training.

6.1 IDENTIFICATION OF SYSTEM ELEMENTS OF GREATEST OVERALL SIGNIFICANCE

Tabulation of the weighted scores for each element of questions 6 through 12 for each questionnaire is included in Appendix D, Volume II. The averages for each element of each system/subsystem in these tables is given first as the simple average of the individual weighted scores. Each of these averages, multiplied by the measure "System Importance", gives the second average on these tables. These scores represent the relative importance of each element to behavioral research within each system/subsystem. The summation of the scores for each element from all systems, and from all subsystems, indicates the relative importance of each element to behavioral research in relation to all systems, or all subsystems.

This procedure enabled the identification of those elements common to all systems/subsystems which are likely to have the greatest bearing on changes in training requirements and consequent needs for behavioral research. As an example of this analysis, the first element of question 6 refers to the difference in "flight controls" between the new system and the current system. If the weighted summation of the answers for this element is large relative to similar sums for other elements, then it may be inferred that the changes in "flight controls" in future systems are both substantial and pervasive.

Using this approach, we identified the three highest scoring elements for each Factor, B through G, (i.e., questions 6 through 11). These high-scoring elements are shown in Table 10 for systems and Table 11 for subsystems.

These results of the scoring model identify new display forms and the monitoring of displays as the major elements of change which will require revision of current training procedures. Changes in flight controls, control responsiveness and maneuverability constitute the second most important elements of change. Flying workload changes (primarily reductions of physical requirements) are the next most important element. Changes in target detection equipment also rate very high in terms of requirements for training

TABLE 10
MAJOR ELEMENTS CONTRIBUTING TO TRAINING DIFFERENCES IN
THE OVERALL FUTURE ARMY AVIATION SYSTEMS (WITH WEIGHTED SCORES)

Factors	Elements
System Characteristics	Displays (1.20) Flight Controls (0.68) Weapon Guidance (0.50)
System Performance	Flying Workload (1.30) Target Detection (0.82) Control Responsiveness (0.57) Maneuverability (0.57)
Crew Operation	Nap-of-the-Earth Flying (0.30) Instrument Flying (0.25) Basic Flying (0.24)
Combat Operation	Air-to-Ground Combat Flying (0.73) Air-to-Air Combat Flying (0.52) Target Detection (0.44)
Man-Machine Requirement	Monitoring Displays (0.69) Decision-Making (0.50) Physical Responses (0.29)
Crew Interaction	Non-Verbal Exchange (0.35)

TABLE 11
MAJOR ELEMENTS CONTRIBUTING TO TRAINING DIFFERENCES IN
THE OVERALL FUTURE ARMY AVIATION SUBSYSTEMS (WITH WEIGHTED SCORES)

Factors	Elements
System Characteristics	Displays (1.13) Flight Controls (0.90) Instruments (0.75)
System Performance	Flying Workload (1.11) Flight Safety (0.52) Target Detection (0.46)
Crew Operation	Nap-of-the Earth Flying (1.28) Instrument Flying (0.50) Navigation (0.32)
Combat Operation	Air-to-Ground Combat Flying (0.40) Air-to-Air Combat Flying (0.32) Weapon Aiming and Firing (0.30)
Man-Machine Requirement	Decision-Making (0.88) Physical Responses (0.50) Monitoring Displays (0.35)
Crew Interaction	Non-Verbal Exchange (0.43) Coordinated Physical Responses (0.18) Verbal Exchange (0.07)

revisions. The high scores for decision-making accurately reflect the survey respondents' comments that the automation of many manual flying activities will shift crew duties to higher decision levels; i.e., toward management of the helicopter as a combat system.

Nap-of-the-Earth (NOE) flying is clearly important, and would rate higher except that it is already an important and well-recognized part of Army aviation training. Although it may not require great changes in training, NOE flying may remain the most critical of all training requirements. Both air-to-ground and air-to-air combat also rated high in terms of requiring changes in training. It is somewhat surprising that air-to-air combat did not score even higher since it represents a totally new operational requirement. It may be that the absence of doctrine and lack of experience in air-to-air combat limited the responses in this area.

6.2 SYSTEM ELEMENTS REQUIRING DIFFERENT OR NEW TRAINING

Elements which require different or new training in the individual systems/subsystems are not necessarily the same elements as those of greatest significance in the overall view. Therefore this section shifts from the overall view given in the previous section to consideration of the most significant elements for each system/subsystem. These "significant" elements requiring different or new training are summarized in Tables 12 and 13. These tables may be used to identify the areas in which changes in training requirements are most important for each system or subsystem.

6.3 REQUIREMENTS FOR DIFFERENT TRAINING METHODS

The survey respondents were asked to comment specifically on their perception of the differences required in training methods between a future system/subsystem and its corresponding current counterpart. This was question number 12 in the survey questionnaire. Tabulation of the scores on this question is given in Appendix D. Air-to-ground combat flight maneuvers, air-to-air combat flight maneuvers, and target attack were considered to be the elements requiring the greatest difference in training methods overall for the five future Army aviation systems. Elements requiring the greatest difference in training methods overall for the seven future subsystems are different from the elements for systems. The survey results indicate that nap-of-the-earth flying, air-to-ground combat flight maneuvers, and instrument flying are the elements requiring the most difference in training methods for the subsystems. Of course, individual systems and subsystems could need different aircrew training methods for elements other than those most important to the group as a whole. Training methods expected to change the most for each aviation system or subsystem are shown in Table 14. Comments on each system and subsystem, based on the survey responses, are included in the following paragraphs.

6.3.1 Far-Term Scout Helicopter

Target detection and air-to-air combat flight represent new missions for scout helicopter operations. Consequently, the Far-term Scout Helicopter would need radically different training methods in air-to-air combat, air-to-ground combat, command and control information processing, target attack, weapon aiming and firing, and target detection.

TABLE 12
SYSTEM ELEMENTS REQUIRING DIFFERENT OR NEW TRAINING

System	Factor	Element (with scores from the Scoring Model Analysis)
Far-term Scout Helicopter	System Characteristics	Flight Controls (0.14) Displays (0.14) Instruments (0.09)
	System Performance	Flying Workload (0.17) Control Responsiveness (0.08) Maneuverability (0.08)
	Combat Operation	Air-to-Air Combat Flight (0.09) Air-to-Ground Combat Flight (0.09)
SMA-X	System Characteristics	Flight Controls (0.13) Displays (0.13) Instruments (0.08)
	System Performance	Flying Workload (0.08) Flight Stability (0.08)
	Man-Machine Requirement	Decision-Making (0.08)
Black Hawk	System Characteristics	Flight Controls (0.32) Display (0.32) Weapon Guidance (0.20)
	System Performance	Flying Workload (0.40) Maneuverability (0.28) Control Responsiveness (0.28)
	Crew Operation	Basic Flying (0.20) Instrument Flying (0.20) Navigation (0.12)
	Combat Operation	Target Attack (0.16) Air-to-Ground Combat Maneuvers (0.16) Reconnaissance (0.16) Command and Control Information Processing (0.16)
	Man-Machine Requirement	Monitoring Displays (0.20) Physical Responses (0.20)
	Crew Interaction	Non-verbal Exchange (0.34)

TABLE 12 (Continued)
SYSTEM ELEMENTS REQUIRING DIFFERENT OR NEW TRAINING

System	Factor	Element (with scores from the Scoring Model Analysis)
Advanced Attack Helicopter	System Characteristics	Displays (0.35) Weapon Guidance (0.11) Flight Controls (0.09)
	System Performance	Target Detection Capabilities (0.26) Maneuverability (0.15) Control Responsiveness (0.15) Flying Workload (0.15)
	Crew Operation	Map-of-the-Earth Flying (0.22)
	Combat Operation	Air-to-Air Combat Maneuverability (0.22) Target Detection (0.10)
	Man-Machine Requirement	Tracking Outside Aircraft (0.22) Monitoring Displays (0.16) Decision-Making (0.15)
Near-term Scout Helicopter	System Characteristics	Displays (0.27) Laser (0.17) Weapon Guidance (0.13)
	System Performance	Flying Workload (0.22) Target Detection Capability (0.08)
	Combat Operation	Air-to-Ground Combat Maneuverability (0.22) Air-to-Air Combat Maneuverability (0.22) Target Attack (0.18)
	Man-Machine Requirement	Monitoring Displays (0.22) Decision-Making (0.22)

TABLE 13
SUBSYSTEM ELEMENTS REQUIRING DIFFERENT OR NEW TRAINING

Subsystem	Factor	Element
ADAS (Army Digital Avionic Systems)	System Characteristics	Displays (0.58) Instruments (0.36) Visibility (0.18)
	System Performance	Flying Workload (0.36) Flying Safety Characteristics (0.18) Complexity (0.11)
	Crew Operation	Map-of-the-Earth Flying (0.72) Navigation (0.22) Instrument Flying (0.18)
	Man-Machine Requirement	Decision-Making (0.36) Physical Responsiveness (0.18) Monitoring Displays (0.18)
	Crew Interaction	Non-Verbal Exchange (0.09)
Landing System	System Performance	Flying Workload (0.08)
	Man-Machine Requirement	Decision-Making (0.08)
A/C Rocket System	Combat Operation	Target Attack (0.15) Weapon Aiming and Firing (0.11)
	Man-Machine Skill	Decision-Making (0.15)
	Combat Operation	Air-to-Air Combat Maneuverability (0.22)
	Man-Machine Skill	Tracking Outside Aircraft (0.22) Decision-Making (0.09)
	Crew Interaction	Non-verbal Exchange (0.13)
	System Characteristics	Visibility (0.10) Weapon Guidance (0.10) Laser (0.10)
Fire Control	System Performance	Target Detection Capabilities (0.24) Flying Workload (0.10)
	Crew Operation	Target Detection (0.24)
	Crew Operation	Target Detection (0.12) Weapon Aiming and Firing (0.09)

TABLE 13 (Continued)
SUBSYSTEM ELEMENTS REQUIRING DIFFERENT OR NEW TRAINING

Subsystem	Factor	Factor
ADOCs (Advanced Digital Optical Control System)	System Characteristics	Flight Controls (0.65) Power Controls (0.30) Displays (0.23)
	System Performance	Flying Workload (0.41) Maneuverability (0.28) Flying Stability (0.24)
	Crew Operation	Nap-of-the-Earth Flying (0.41) Basic Flying (0.20) Instrument Flying (0.20)
	Man-Machine Skill	Physical Responses (0.20)
	Crew Interaction	Non-Verbal Exchange (0.10)
IDSV (Integrated Digital System Validation)	System Characteristics	Flight Controls (0.26) Displays (0.26) Instruments (0.16)
	System Performance	Flying Workload (0.16) Maneuverability (0.11) Control Responsiveness (0.11)
	Crew Operation	Nap-of-the-Earth Flying (0.16) Basic Flying (0.08) Instrument Flying (0.08)
	Combat Operation	Air-to-Ground Combat Maneuvers (0.32) Air-to-Air Combat Maneuvers (0.16) Target Attack (0.13)
	Man-Machine Skill	Extensive Man-Machine Integration (0.19) Decision-Making (0.16) Monitoring Displays (0.08) Tracking Outside Aircraft (0.08)
	Crew Interaction	Non-Verbal Exchange (0.10)

TABLE 14
 REQUIREMENTS FOR DIFFERENT TRAINING METHODS
 IN AVIATION SYSTEMS/SUBSYSTEMS (SURVEY QUESTION NO. 12)

System/Subsystem	Different Training Methods (with scores)
Far-term Scout	Air-to-Ground Combat Maneuvers (0.14) Air-to-Air Combat Maneuvers (0.09) Target Attack (0.07)
SEMA-X	Air-to-Air Combat Maneuvers (0.04) Basic Flying (0.02) Command and Control Information Processing (0.02)
Black Hawk	Air-to-Ground Combat Maneuvers (0.40) Air-to-Air Combat Maneuvers (0.20) Target Attack (0.16) Reconnaissance (0.16) Command and Control Information Processing (0.16)
Advanced Attack	Air-to-Air Combat Maneuvers (0.16) Nap-of-the-Earth Flying (0.11)
Near-term Scout	Air-to-Ground Combat Maneuvers (0.20) Air-to-Air Combat Maneuvers (0.13) Weapon Aiming and Firing (0.07)
ADAS	Nap-of-the-Earth Flying (0.72) Navigation (0.22)
Landing Subsystem	Instrument Flying (0.04)
Aircraft Rocket Subsystem	Weapon Aiming and Firing (0.05)
Aircraft Guns	Air-to-Air Combat Maneuvers (0.11) Air-to-Ground Combat Maneuvers (0.09) Target Attack (0.07)
Fire Control	Weapon Aiming and Firing (0.03) Target Detection (0.01) Multiple Aircraft Operations (0.01)
ADCS	Nap-of-the-Earth Flying (0.41) Instrument Flying (0.20) Basic Flying (0.08)
IDSV	Air-to-Ground Combat Maneuvers (0.32) Cargo Operation (0.19) Air-to-Air Combat Maneuvers (0.16) Nap-of-the-Earth Flying (0.16)

6.3.2 SEMA-X Aircraft

Training methods for air-to-air combat flight maneuvers will be radically different, while substantially different methods will be used in basic flying and command and control information processing. Greater use of synthetic displays will require somewhat different training methods in instrument flying and reconnaissance.

6.3.3 Black Hawk Helicopter

Substantial differences will be required in training methods in Black Hawk helicopters for target detection, target attack, weapon aiming and firing, air-to-air combat flight maneuvers, air-to-ground combat flight maneuvers, reconnaissance, and command and control information processing.

6.3.4 Advanced Attack Helicopters

The main change in training methods in future Advanced Attack Helicopters will be in air-to-air combat maneuvers and nap-of-the earth flying. No doctrine currently exists for air-to-air combat.

6.3.5 Near-Term Scout Helicopters

Air-to-air and air-to-ground combat maneuvers will require radically different training methods in the Near-term Scout Helicopters. These scout helicopters also need substantially different training methods in target detection, target attack, weapon aiming and firing and reconnaissance, battle coordination, observer training, pilot workload, new avionics, and usage of simulators.

6.3.6 ADAS (Army Digital Avionic Systems)

Training methods in nap-of-the-earth flying and navigation will be radically different if the ADAS system is introduced.

6.3.7 Landing Subsystem

The proposed new landing subsystem will require somewhat different training methods for instrument flying.

6.3.8 Aircraft Rocket Subsystem

The postulated aircraft rocket subsystem will require somewhat different training methods in weapon aiming and firing activities.

6.3.9 Aircraft Guns

Aircraft gun subsystem capabilities will require substantially different training methods for air-to-air combat, target detection, target attack, and weapon aiming and firing.

6.3.10 Fire Control Subsystems

New fire control subsystems will require substantially different training methods in weapon aiming and firing.

6.3.11 ADOCS (Advanced Digital Optical Control System)

The ADOCS will need substantially different methods for instrument flying and NOE flying training.

6.3.12 IDSV (Integrated Digital Systems Validation)

The IDSV will bring about substantial changes in training methods for nap-of-the-earth flying, basic flying, instrument flying, navigation, communication, multiple aircraft operations, reconnaissance, and command and control information processing.

SECTION 7

EXPECTED CHANGES IN TRAINING REQUIREMENTS

Changes in training requirements which may be expected as a consequence of the incorporation of new technologies in Army aviation systems flow logically from the scoring model analysis described in the previous sections. This section builds on the previous analysis by defining the additions to and deletions of current training practices which are likely to be needed in the future.

An important aspect of establishing training requirements is the capability of the trainee population to respond to the training which might be offered. This concern was expressed frequently in the interviews. Therefore, the next section discusses the probable Army aviation trainee population under various circumstances.

The major areas of change in training requirements will be: (a) adaptation to new display technologies; (b) adaptation to new flight controls and control characteristics; (c) much greater emphasis on target detection, acquisition, aiming, and firing; (d) training for air-to-ground combat in high threat scenarios; (e) training for air-to-air combat against enemy helicopters; (f) adverse-weather training; (g) night Nap-of-the-Earth operations; (h) training for rapid deployment; and (i) increased use of objective performance measurement in training evaluation. Each of these changes is discussed in detail in the paragraphs which follow.

7.1 ADAPTATION TO NEW DISPLAY TECHNOLOGIES

A principal feature of many of the new display technologies is that at any given time they will present only that information which is relevant to the decisions required at that time. Therefore, training in scanning a large array of instruments for a few signals of importance will be replaced by training for quick response to situation signals as they appear. Initially, cues will tend to be primitive replications of the cues provided by current instruments. Later, these will be replaced by elaborate graphic indicators that approximate the redundancy of "real world" images. Finally, the cues will be designed to give the optimum amount of information to elicit the swiftest correct responses.

Since the first generation displays will give cues similar to those presented by current instruments, the training changes will be oriented to cue recognition by character rather than by instrument locations. For example, although altitude information might always appear in the same location on the display, it might be displayed only when changing, or when called for by the crew. The crew would recognize that information about altitude was being presented because of the characters appearing, rather than by looking at a specific place, such as the altimeter location, for such information. As the cues become more graphical, training will adjust to crew responses which reject excess information. For example, map presentations often, for the sake of completeness, present detail which is unneeded for the task at hand. Ultimately, when the cues are adjusted to meet piloting needs, pilot adaptation to the available cues will be minimized. In short, this aspect of training will become almost automatic.

The new display forms will also include information on the status of systems and subsystems. This information, coupled with "graded" programming of controls, will eliminate checklist-type training. The control systems will prevent the crew from ignoring essential sequences of action. In addition, the displays and cues will lead the operator through the correct sequence of actions. For example, the display or cue will not frustrate the operator by informing him that "you have taken the wrong action." Instead, the display will tell the operator what corrective action is required.

New types of training will be needed to correct problems caused by the multiple images provided by the new displays. Integrating the visual perception of references outside of the cockpit with cockpit displays such as HUD introduces vertigo and disorientation. Images from different sensors, such as those from optical devices and FLIR, and from monocular NVS and the unaided eye, will require special training in how to observe and perceive two or more such images simultaneously. Visual presentations with different reference axes, such as the simple case of parallax between the mast-mounted sight and the cockpit view, and the more complicated case of weapon-aiming devices with six-degree-of-freedom axes separation from aircraft motion, will require new procedures both in simulation and in flight training.

7.2 ADAPTATION TO NEW FLIGHT CONTROL CHARACTERISTICS

Better control response and increased maneuverability will make basic flying easier and therefore should reduce the amount of time allotted in the syllabus for such training. However, using this increased performance to improve combat capabilities will require more training specifically oriented to combat operations. Because of the expense, risk, and limitations of combat flight training, much of this training must be accomplished in simulators. Simulators have proven to be very effective, and in some respects are even better than actual flight for teaching combat activities. However, much more work is required to develop the full potential of simulators for both air-to-ground and air-to-air combat. In addition, since full-task simulators are themselves quite expensive, as much of the training as possible must be shifted to part-task trainers. The part-task learning should provide pre-training that will optimize use of the time spent in the full-task trainer. For example, the student should enter the full-task simulator fully qualified to "solo," without further instruction. After sessions in the full-task simulator have identified specific needs for additional practice, part-task training should be available for such purposes.

7.3 TARGET DETECTION, ACQUISITION, AIMING, AND FIRING TRAINING CONSIDERATIONS

A great deal of effort will be required to develop the training systems and procedures necessary for crews to obtain proficiency in the various phases of target attack through simulation. Because the training display hardware can be identical with the operational display devices, no additional effort is required for hardware development. Development of the training system concepts and procedures will be essential in determining the type of software required for inputs. For example, the input to the displays could be either computer-generated information or reproductions of actual sensor inputs

obtained under field conditions. Procedures for control and evaluation in the training process would be similar to those for other simulator devices.

An important part of this training for target attack will be the development of crew confidence that the training will indeed enable them to find, lock-on to, fire at, hit, and destroy targets under combat conditions. Because the expense of flight operations, maintenance of combat ranges, and cost of practice runs is too high to provide extensive opportunities for real-life practice, the simulation must be very effective. Also, the critical need for maximum effectiveness at the very beginning of combat, i.e., first-day operations, means that there will be no time for battlefield learning. One essential need in developing crew confidence is the paradoxical requirement that random failures of system components be included in the simulator routine. The requirement for such simulated failures is independent of and in addition to the inclusion of systems failures which are intended to elicit corrective action by the crew. That is, the crew should be trained to expect some "dud" rounds, missile failure to lock-on, etc., to a degree commensurate with their perception of field reliability. This concept of simulated imperfection to build confidence, while not entirely new to training, will be of increasing significance in simulator training in the use of the new target detection, acquisition, and aiming devices, and for the associated weaponry.

7.4 TRAINING FOR AIR-TO-GROUND COMBAT

Much of the target attack training discussed above can be accomplished in part-task simulators, and certainly fundamental operations can be learned and practiced on such devices. However, becoming truly qualified for combat requires training in all aspects of air-to-ground warfare in high threat scenarios. The limited opportunities for and high cost of war games practically dictates that they can be used only to validate overall training effectiveness and to disclose weaknesses in battle force concepts and capabilities. Therefore, individual crews must be fully trained before they participate in war games. Combat ranges provide the ideal training situation for air-to-ground combat. However, the cost of acquiring and operating such ranges limits the opportunities for training in the full-scale realistic combat environment they provide. Therefore, full-task simulators will be required to train crews in air-to-ground combat operations. This full-task training must include realistic threat simulation. The training for air-to-ground combat should provide the simultaneity of actions required in actual combat. That is, the search for and attack on targets should be accomplished under conditions of potential or active enemy response, and with simulation of natural hazards such as towers, cables, trees, and poor visibility.

7.5 TRAINING FOR AIR-TO-AIR COMBAT

Training for air-to-air combat will necessarily start at a less complete level. In the beginning it will be difficult to separate training from the development of doctrine, since the tactics needed for survival and victory in air-to-air combat are not yet defined. Development of doctrine will be paced by the availability of helicopter air combat simulators for experiments to determine the maneuvers and tactics most likely to be successful. Some actual flight exercises in air-to-air combat will be required to validate the results

of the simulator experiments. Once the appropriate doctrine, tactics, and maneuvers are known, the training for air-to-air combat can be designed. It is most important that training for air-to-air combat begin after the experimentation and validation described above has been completed. Otherwise, poor doctrine and bad habits will become ingrained in the system and will be difficult to eradicate. Early disasters in aerial combat between conventional aircraft in World War II indicate the hazards of venturing into battle with unproven doctrine and tactics. Until the advent of simulators, such experiences were mostly unavoidable. Today, such failures are inexcusable. Air-to-air combat must be planned for, and adequate training is mandatory.

7.6 TRAINING FOR ADVERSE WEATHER OPERATIONS

Although weather-related problems were not emphasized during the survey discussions, it appears that training for adverse weather operations will play an increasing role in the curriculum. This seems almost implicit in the discussion of night operations. The problem seems to be one of avoiding "traditional instrument training" which emphasizes air traffic control procedures. Instead, training for all-weather operations should shift emphasis to the following areas: (a) navigation over hostile territory, (b) operation in icing conditions, (c) landing at forward operating locations in limited visibility, and (d) assuring separation from other aircraft. Training issues will include: (a) combining adverse weather with the advanced displays such as FLIR and HUD, (b) determining the extent and feasibility of exposure to actual conditions versus simulator training, (c) developing the flying procedures required for the operations listed above, and (d) determining how to provide training in those procedures. In the absence or limited availability of combat ranges, it will also be necessary to find ways to integrate actual flying training in real or simulated adverse weather with the available domestic airspace. For instance, flying operations in the southern U.S. are unlikely to duplicate the weather conditions in northern Europe. Even the deserts in the western U.S. provide scanty simulation of the Sahara and the Mid-East desert conditions.

7.7 TRAINING FOR NIGHT NOE OPERATIONS

Night-time Nap-of-the-Earth operations will obviously require special training. It is not clear if current simulators offer effective training for low-light-level NOE flight. It seems likely that electronic simulation of views through the cockpit windows would be a better choice for future development of night training devices. Since night flying cues will be provided by the Pilot Night Vision System (PNVS) as images on an electronic screen, the playback of recorded real-life images on a replica of the PNVS should provide realistic training. However, transition from PNVS to outside viewing, and simultaneous observation of both electronic and outside images, are problems that will require attention as training devices and programs are developed. Because of the hazards involved in actual night NOE flight, pilots will need to be fully night-qualified in simulators before they attempt helicopter flight under simulated night conditions, i.e., with hoods for the trainee while the instructor pilot retains visual daylight observation. In spite of the apparent emphasis given to night NOE operations, it appears that

much remains to be accomplished in training in this area. In particular, the development and use of electronic aids for night vision must be integrated with natural cues and other pilot-aiding systems.

7.8 TRAINING FOR RAPID DEPLOYMENT

Rapid deployment is a matter of increasing importance with major implications for Army aviation training. Long-range navigation, in-flight refueling, and heavy-lift helicopter operations will need greater emphasis in training to support rapid deployment. The "backwards" cockpit and controls used for hover and hook-up loading operations in heavy-lift helicopters will require special training and perhaps selectivity in crew assignments. Initial training and practice for all three of the above tasks can be accomplished on part-task simulators. Other tasks associated with rapid deployment which will require changes in training may be disclosed as a result of further development and practice in this area.

7.9 INCREASED USE OF OBJECTIVE PERFORMANCE MEASUREMENT

The last major area of change in training identified in this study is the increased use of objective performance measurement. This change is associated with the continued development of part-task and full-task simulators, and the availability and sophistication of in-flight recording devices. If there is a "best way" to perform a given task, it can be recorded as the standard. Student deviation from the standard is measurable. Correction can concentrate on specific faults, and practice can reinforce correct actions. The impact on training is a shift of emphasis away from instructor monitoring and evaluation toward development of recorded standards. Greater efficiency in training will be achieved since much better records of training performance will be automatically available, without the tedious and often omitted manual recording of student progress through training.

SECTION 8
PERSONNEL AVAILABILITY

Training methods should be constructed on the basis of the characteristics of hardware, the tasks for which that hardware is used, and the social-cultural characteristics of the population trained. Pressures to change trainee entry requirements, such as levels of education achieved and physical fitness, could emanate from a change in the number of trainees and/or a change in the size of the population pool from which trainees are drawn. Pressure for increased utilization of women also could result from a change in the ratio of trainees to population pool.

The Army has approximately 1,650 helicopter pilot trainees each year. Two-hundred and fifty of these trainees are non-prior service; the remainder come from prior service personnel. To maintain this number of trainees while at the same time maintaining present numbers in other programs, the Army has to recruit 250 persons who enter helicopter pilot training shortly after induction and approximately 1400 persons to replace personnel drawn from other Army programs for entry into this training.

To determine the ease or difficulty with which 1,650 qualified persons can be supplied for Army helicopter pilot training, some comparative base must be used. The base chosen was annual Army accessions of Category I and II, non-prior service males. These categories are determined currently by scores on the general aptitude portions of the Armed Services Vocational Aptitude Battery (ASVAB) test. The exact breakdown, in percentiles, is: Category I--93 to 100; II--65 to 92; IIIA--50 to 64; IIIB--31 to 49. Besides the availability of data, [25] several reasons justify using this base. Helicopter pilot trainees are predominantly male. Mental requirements for entry into and successful completion of the training program are high.

For 1977, the Army had an accession of 21,242 non-prior service Category I and II males. [26] Of this pool, Army helicopter pilot training utilized 4.71 percent (i.e., 1,000/21,242). Of this total, 1.18 percent (i.e., 250/21,242) were selected for helicopter pilot training shortly after induction and 3.53 percent (i.e., 750/21,242) were required to replace personnel drawn away from other Army elements for helicopter pilot training. The percentage of the pool utilized can suggest the ease or difficulty in recruiting trainees and the pressures for changing entrance requirements and/or recruiting trainees from other pools.

The percentage of non-prior service Category I and II male accessions utilized for helicopter pilot training as an indicator of ease/difficulty in recruiting trainees is less than precise for a variety of reasons. Trainees include women. Excluding women from the pool inflates the percentage and may suggest that recruiting is more difficult than it is. The assumption was made that prior service personnel who enter training must be replaced with Category I and II personnel. If the prior service personnel are replaced with less than Category II personnel, this exercise may suggest that recruiting replacements for trainees may be more difficult than is actually the case. Finally, some persons who may not pass physical requirements for Army aviation are included in the pool. Not excluding these persons from the pool deflates the percentage and may suggest that recruiting trainees is easier than is the case.

The ease/difficulty of recruiting adequate numbers of qualified personnel to meet the demands of Army helicopter pilot training was illustrated in two scenarios: voluntary recruitment, and a mobilization with a draft. In the voluntary recruitment scenario, the level of 1,650 yearly trainees and an increased level of 2,000 yearly trainees were studied. In the mobilization with a draft scenario, a level of mobilization for World War II was studied. The levels of mobilization for the Korean and Vietnam conflicts appeared to require approximately 2,000 yearly trainees--the same number as the increased level under the voluntary recruitment scenario.[27] Consequently, these levels of mobilization were not studied separately.

8.1 VOLUNTARY RECRUITMENT SCENARIO

Predictions of non-prior service Category I and II male voluntary accessions were made by Fernandez for the period 1980 to 1990.[28] The Fernandez report was selected for this analysis, in spite of the shortcomings noted later, in Section 8.3, because it was cited several times in the interview survey as one of the primary models actually being used for projections of Army enlistments. Although other models may also be in use, they were not cited in the interviews. Our limited search for other models did not discover other quantitative models, and development of a better model would have been beyond the scope of this study.

Fernandez based his predictions on actual voluntary Army enlistments between FY 1971 and FY 1979, the adjusted 17 to 21 year old male population in the United States, the ratio of military pay to civilian pay, the youth unemployment rate, the number of Army production recruiters and an unnamed factor which first appeared in FY 1978 and has decreased military accessions. Fernandez predicted Army accessions for scenarios of low, moderate, and high economic growth suggesting high, moderate, and low youth unemployment. In the present analysis, only the low and high growth scenarios are considered because these present the "best" and the "worst" possible situations for Army accessions.

Fernandez used multi-variate regression analysis for his prediction of accessions. Two points should be made concerning the statistical qualities of this model. First, not all determinants of accessions have been established and entered into the prediction formula. However, the square of the multiple correlation of the predicted variable with the predictor variables was .90, indicating that only 10 percent of the variation in the predicted variable was unaccounted for by the four predictor variables.[29] Thus, the model should be considered to be relatively good from this standpoint.

Second, the model is built utilizing sample data and may not adequately represent the population because of sampling error. To judge the probability that sampling error has distorted the predictions, a confidence interval (i.e., a range of values in which the correct prediction should fall) is calculated with a certain confidence level (i.e., the probability that the exercise has produced a range of values in which the true predicted value lies). Using Fernandez's predictions, the confidence intervals for high economic growth (i.e., low unemployment) and low economic growth (i.e., high unemployment) at the .95 confidence level were calculated.[30] The lower limit of the high growth interval represents the "worst" possible situation

for Army accessions and the upper limit of the low growth interval represents the "best" possible situation for Army accessions. These limits are presented in Table 15. Corresponding percentages of the pool which 1,650 men and 2,000 men would represent were also calculated and are also presented in Table 15.

A perusal of Table 15 indicates that Army aviation, even in the "best" possible accessions situation, will be using a higher percentage of the accessions for helicopter pilot training throughout this decade than in 1977, if the annual level of 1,650 helicopter pilot trainees is continued. The peak year would be 1990, in which the Army would have to use 8.9 percent of its accessions for helicopter pilot training. This is more than a 4 percent increase over the 1977 level. On the other hand, given the "worst" possible situation, the Army would have to utilize much higher percentages. In 1981, 14.47 percent would have to be utilized, and this increases almost yearly to 22.29 percent in 1990.

If the Army increased its utilization to 2,000 men, the impact is immediately dramatic, given even the "best" possible accessions situation. Utilization of 2,000 men requires 9.12 percent of the pool in 1981 and this percentage increases almost steadily to 10.79 percent in 1990. Given the "worst" possible accessions situation, the impact of increased utilization is staggering. In 1981, 17.54 percent of the pool would have to be utilized and this increases almost steadily to 27.02 percent in 1990.

If the Army continued to train approximately 1,650 helicopter pilots annually, and given the most optimistic predictions for Army accessions, little pressure would emanate from the changing size of the population pool to utilize personnel other than males who meet high entrance requirements. However, an increase in the annual number of trainees and/or a "less-than-best" accession situation would almost certainly strain the program.

8.2 MOBILIZATION DRAFT SCENARIO

In a mobilization similar to that which occurred just prior to and during World War II, extensive demands can be anticipated on the manpower pool available to become helicopter pilots. This scenario projects how deeply the helicopter pilot requirements will dip into the manpower pool during a typical mobilization effort. Two baseline training rates (1,000 per year and 2,000 per year) are chosen. In the simulated model which follows, the 1978 Army end strength of 757,000[31] is projected to grow to the post-World War II strength of 8,267,958[32] in a three-year period from 1984 to 1987. This is approximately an 11 times increase. It is assumed that the helicopter training rate will grow by the same ratio as the end strength during this period, i.e., increase about 11 times to 11,000 per year or 22,000 per year depending on the base line training rate selected.

The non-prior service male population between the ages of 17 and 21 years of ages is collected from Census data and shown in Table B.7 of Fernandez, projected through the year 1990. Mental Categories I and II comprise the top 35 percent of this projected population. Assuming that the helicopter pilot trainees come from Category I and II reduces the population to 35 percent of the size shown in Table B.7 of Fernandez. A further

TABLE 15
 PREDICTED ARMY ACCESSIONS OF CATEGORY I AND II NON-PRIOR SERVICE MALES
 AND PERCENT OF POOL UTILIZED FOR ACTIVITIES
 RELATED TO ARMY HELICOPTER PILOT TRAINING, 1981-1990

Predicted Army Accessions of Category I and II, Non-Prior Service Males				
Year	Lower Limit	Upper Limit	Range of Percent of Pool	
	High Economic	Low Economic	Needed to Utilize	
	Growth Scenario	Growth Scenario		
	(Low Unemployment)	(High Unemployment)	1,650 Men	2,000 Men
1981	11,404	21,929	7.52-14.47	9.12-17.54
1982	10,207	21,651	7.62-16.16	9.24-19.59
1983	8,751	21,056	7.84-18.85	9.50-22.85
1984	8,096	20,277	8.13-20.38	9.86-24.70
1985	7,835	19,578	8.43-21.06	10.22-25.53
1986	7,625	19,054	8.66-21.64	10.50-26.23
1987	7,550	18,836	8.76-21.85	10.62-26.49
1988	7,595	18,921	8.72-21.72	10.57-26.33
1989	7,590	18,948	8.70-21.74	10.55-26.35
1990	7,402	18,528	8.90-22.29	10.79-27.02

reduction of the pool size is accomplished through the physical examination for flying duty. Experience gathered from medical examinations of helicopter flight training candidates indicates that this reduction will be approximately 19 percent.[33] This calculation of the non-prior service male population projected for the years 1980 to 1990, and corrected for mental and physical requirements of helicopter flight training, is shown in Table 16.

Figure 2 shows the percentage of the available male population taken into helicopter flight training each year for the two base line training rates selected. Figure 3 shows a mobilization to World War II levels of strength in the years 1984 to 1987. The change in percentage taken from the pool of potential helicopter pilots is significant during a mobilization considering the demands placed on this same group of people from the Air Force and Navy pilot programs as well as other branches of all the services. In a mobilization lasting over an extended time period it is likely that pressures to lower mental and physical standards for flying training will be experienced. Increased utilization of women in non-combat flying roles is an alternative to lowering mental and physical standards that needs to be investigated as more experience with female helicopter pilots is obtained.

8.3 OTHER DATA RELATED TO PERSONNEL AVAILABILITY

As noted previously, the Fernandez predictions of Army volunteer accessions include a projection of the 17 to 21 year-old male population in the U.S. for the period from 1980 to 1990. However, this 17 to 21 year-old population projection is not separately observable in the prediction of accessions. Because of the strong effect of population supply in relation to Army demands for personnel, it is useful to present such a projection separately. Therefore, total U.S. native-born populations in the 18 to 24 year-old group, for the years 1984 to 2000, are presented in Figure 4. Although Army accessions come predominantly from the lower half of the 18 to 24 year-old group, the total group is more meaningful in terms of Army manpower demands. First-term reenlistments come from the upper half of this group and reductions in such reenlistments must be offset by additional accessions. Most notable in this data is the abrupt decline in the size of 18 to 24 year old group after 1982. This decline, which will show up somewhat earlier in the 17 to 21 year-old group, is not a surprise to anyone who takes even a cursory look at population trends. However, the magnitude and persistence of the downward trend will be of major importance to the Army in meeting its personnel needs. It is beyond the scope of this study to develop a model for prediction of Army accessions. However, sufficient information is available to support some conclusions with respect to probable outcomes.

First, it must be noted that the Fernandez multivariate model is based on data for the period from 1971 to 1979. The 17 to 21 year-old population group was stable in size throughout this period, and was somewhat larger than would occur in a uniform population state. Thus the Fernandez model is subject to serious prediction errors for situations in which the age group of military interest is substantially below the 1971 to 1979 levels. This clearly will occur as that population drops to 93 percent of the 1979 level by 1985, to 86 percent by 1990, and to 79 percent by 1995. The problems for Army personnel staffing and the errors resulting from use of the Fernandez model

TABLE 16
ESTIMATION OF MALES AGE 17-21 QUALIFIED TO FLY HELICOPTERS RELATED TO CENSUS POPULATION

Year	Population in Thousands										Percentage of Qualified Pool Extracted at Training Rates			
	Age										Physical Qualification		1000	
	17	18	19	20	21	Total 17-21	Mental Categories CAT. I & II 35%	Physical Qualification 81%	Per Yr	2000	Per Yr	11000	Per Yr	22000
1980	2095	2080	2013	1960	1861	10009	3503	2837	.03525	.0705	.3877	7755		
1981	2064	2049	1975	1980	1845	9913	3470	2811	.03557	.07115	.3913	7826		
1982	1973	2019	1945	1943	1866	9746	3411	2763	.03619	.07239	.3981	7962		
1983	1871	1930	1917	1914	1879	9511	3329	2696	.03709	.07418	.4080	8160		
1984	1818	1829	1832	1887	1801	9167	3208	2598	.03849	.07698	.4234	8468		
1985	1782	1778	1738	1803	1776	8877	3107	2517	.03973	.07946	.4370	8741		
1986	1805	1743	1689	1711	1697	8645	3026	2451	.0408	.0816	.4488	8976		
1987	1850	1766	1656	1663	1610	8545	2991	2423	.04127	.08254	.454	908		
1988	1887	1810	1677	1630	1566	8570	3000	2430	.04115	.08230	.4527	9053		
1989	1731	1845	1719	1651	1535	8481	2968	2404	.0416	.08319	.4576	9151		
1990	1640	1692	1753	1691	1554	8330	2916	2362	.04234	.08467	.4657	9314		

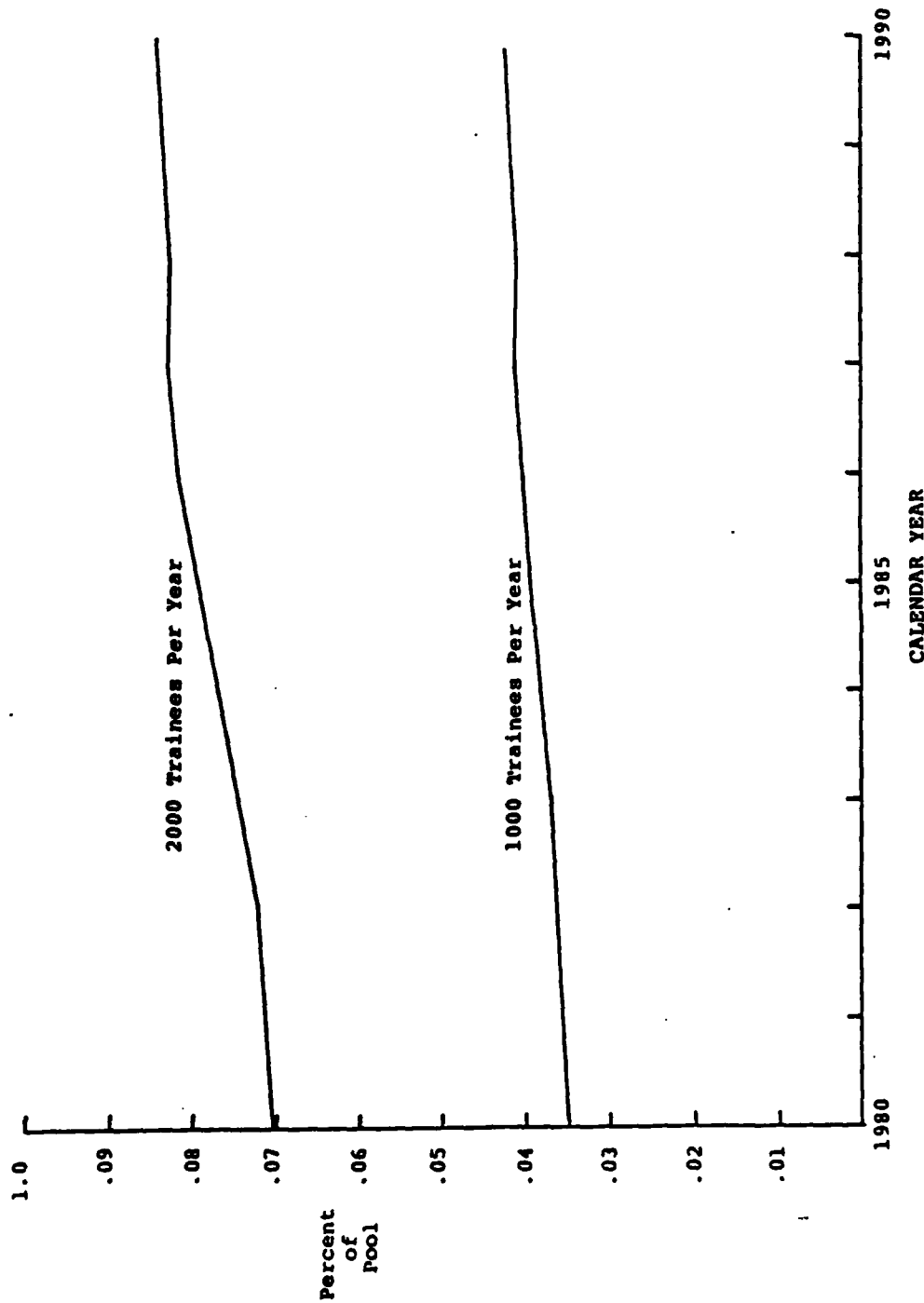


Figure 2. Helicopter Pilot Percentage of Qualified Manpower at Constant Training Rates, based on Census Population.

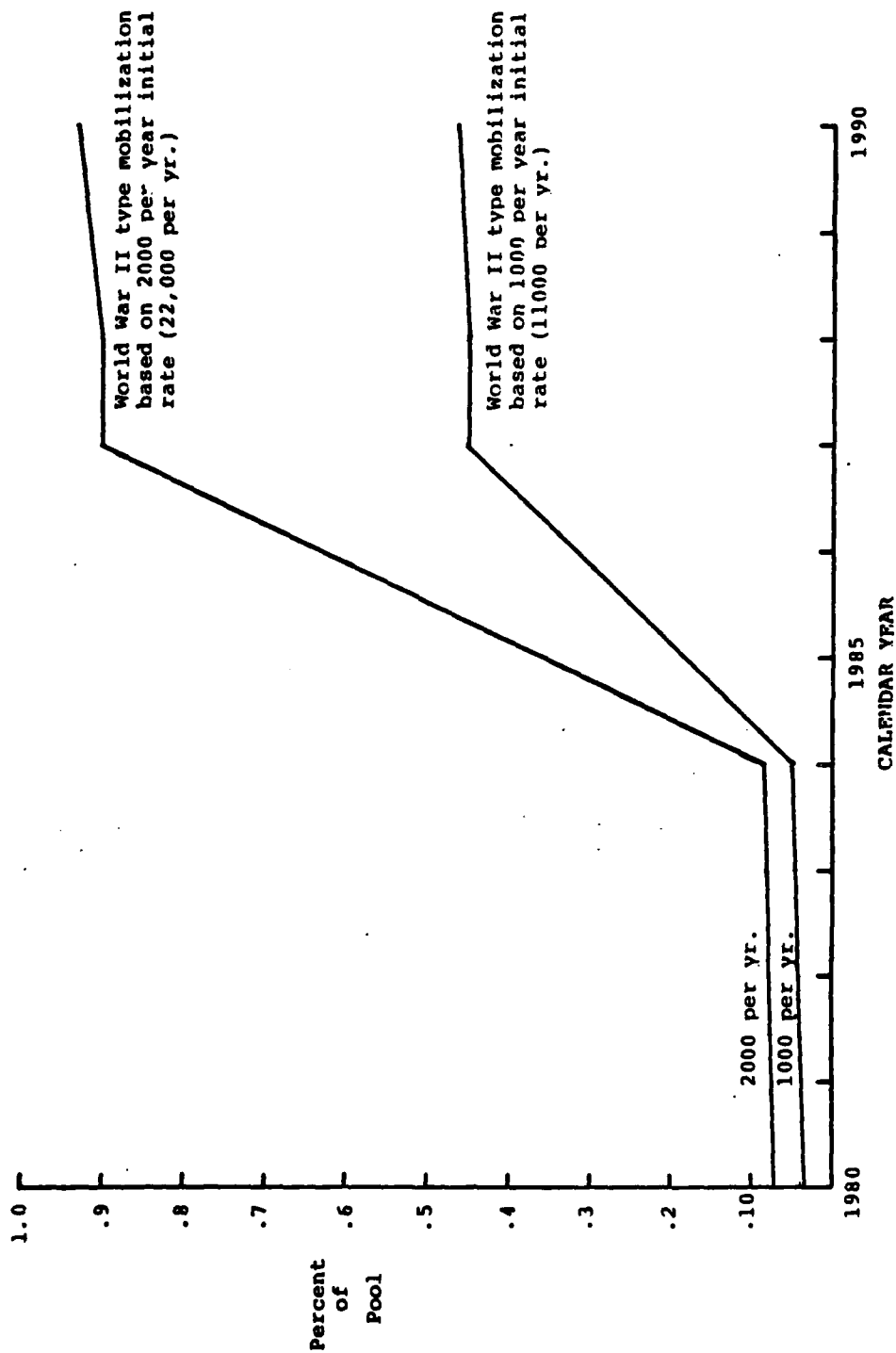


Figure 3. Helicopter Pilot Percentage of Qualified Manpower in a WWII Type Mobilization.

MILLIONS
OF PERSONS

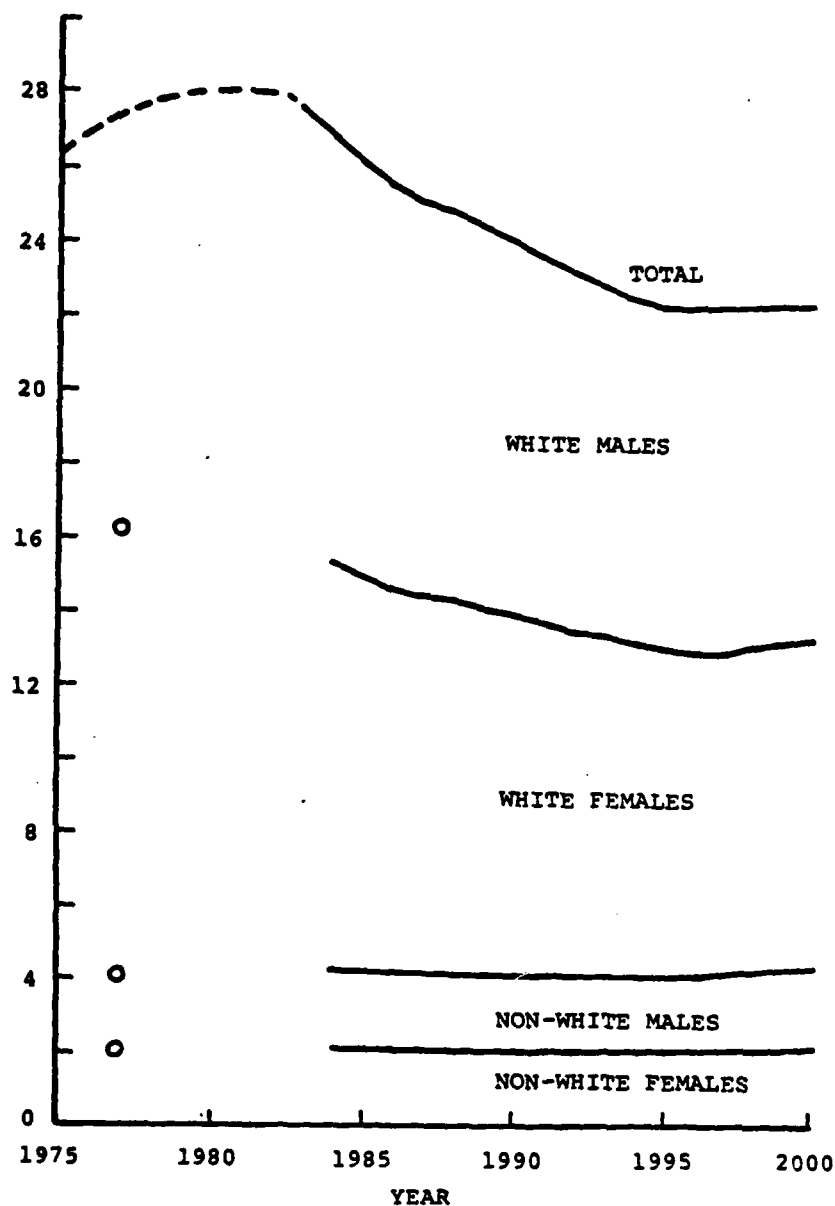


Figure 4. Total U.S. Native-born Populations in the 18-24 Year-old Category. (Data from Statistical Abstract of the United States, Tables 81 and 101 in 1979 edition.)

are much larger than these percentage figures would indicate. That is, a 10 percent drop in the population of the 18 to 24 year-old age group is likely to result in a much larger drop in Army accessions for the following reasons. First, the competition for this age group will be extremely severe. Business, colleges, and the other military services will all be competing for the constantly shrinking population. The constant or even increasing demand in the face of shrinking supply will inevitably drive up the price of the services of this age group. Those who pay the least for these services will receive none or will get the lowest quality. Therefore the Army (and others as well) must either be prepared to bid higher for the services desired, or to change or lower standards of acceptance. Second, this competition was much less during the period covered by the Fernandez study, so that the model does not reflect the effects of the competition on voluntary accessions.

Figure 5 presents the same data as Figure 4 in a slightly different manner to show more easily the numbers of persons in each category each year.

Trends in educational levels are also a significant factor to consider in Army accessions and training. Figure 6 shows that the percentage of high school graduates from a given initial population increased steadily from 50 percent for the graduation class of 1950, to 75 percent for the class of 1968, and remained constant at the 75 percent level throughout most of the 1970s. [34] Thus, on the face of this evidence, the available total pool of persons shown in Figure 4 should be reduced by 25 percent, if high school graduation is a requirement. However, since the decision to enter college is at least a temporary, and often a permanent, decision not to enter military service, the lower line on Figure 6 assumes special significance. This line represents the high school graduates who do not elect to enroll in college. Because more and more individuals have decided to go on to college, the percentage (based on the original group) of high school graduates available for other activities remained nearly constant at 30 percent throughout the period from 1950 to 1968. As indicated earlier, the shrinking personnel pool over the next 15 years will invoke continuing strong pressure from colleges to enroll at least their present share of high school graduates. Therefore the actual pool of graduates which must be shared by industry and the services is not likely to exceed 30 percent of the total personnel in the 18 to 24 age group.

Another trend of concern is the increasing percentage of arrests of persons in the 18 to 24 year-old age group. Arrest records have at least three effects with regard to personnel availability: (a) if absence of an arrest and conviction is among the criteria for selection of Army helicopter pilot trainees, then the available pool is obviously reduced by the number of personnel with criminal records; (b) to the extent that the Army is viewed as requiring adherence to rules and regulations, persons with arrest records will tend not to subject themselves voluntarily to such discipline; and (c) if criminal behavior is continued after entry into service, replacement accessions will be required. The number of 18 to 24 year-old persons arrested is shown by the lower solid line in Figure 7. This data is expressed in percent of the total population of that age group in Figure 8, together with a projection of the arrest percentage from 1978 to 2000, assuming continuation of the trend on an asymptotic approach to a maximum of 20 percent by the year 2000. The rationale for this projection is that no early reversal of the

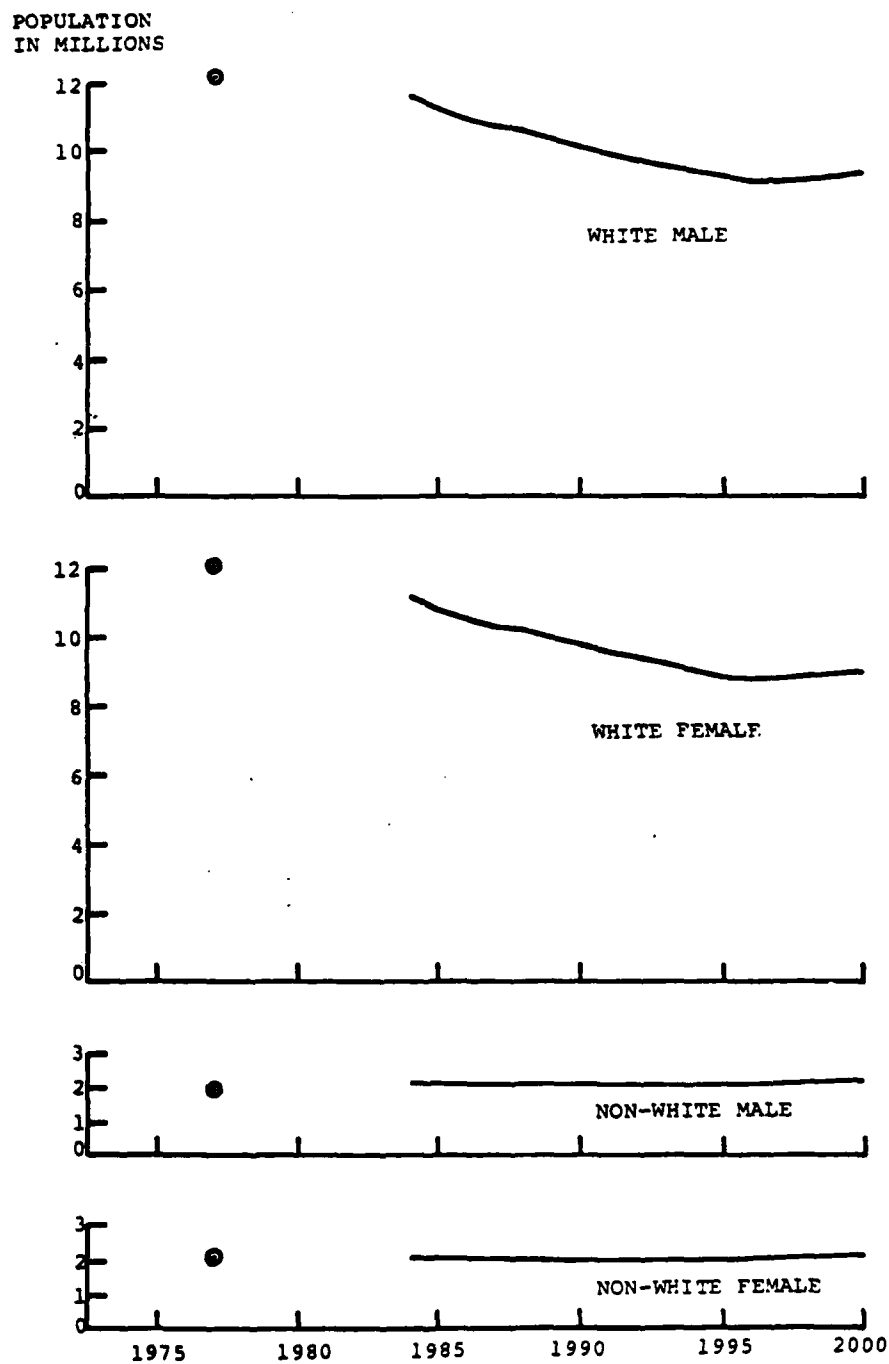


Figure 5. U.S. Native-born Populations in the 18-24 Year-old Category.

PERCENT OF
FIFTH GRADE CLASS

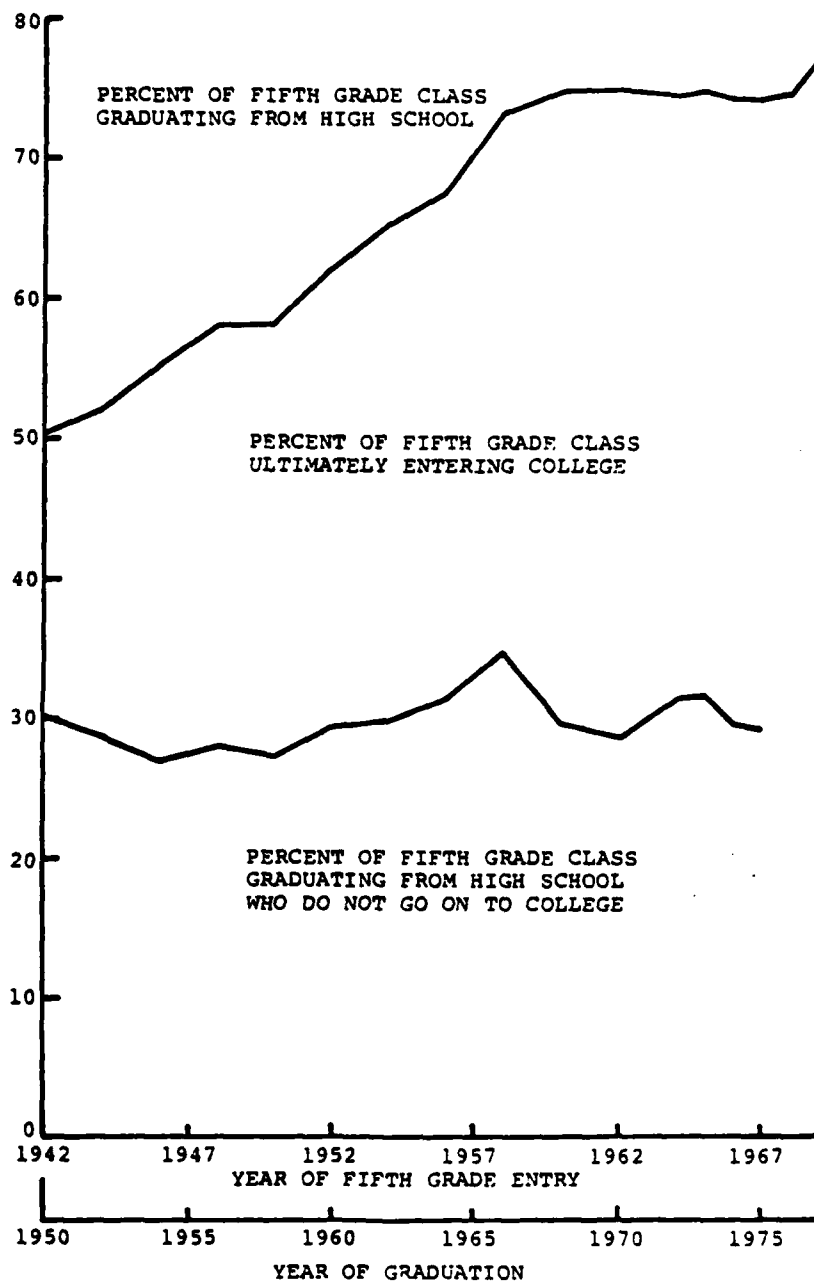


Figure 6. School Retention Rates.

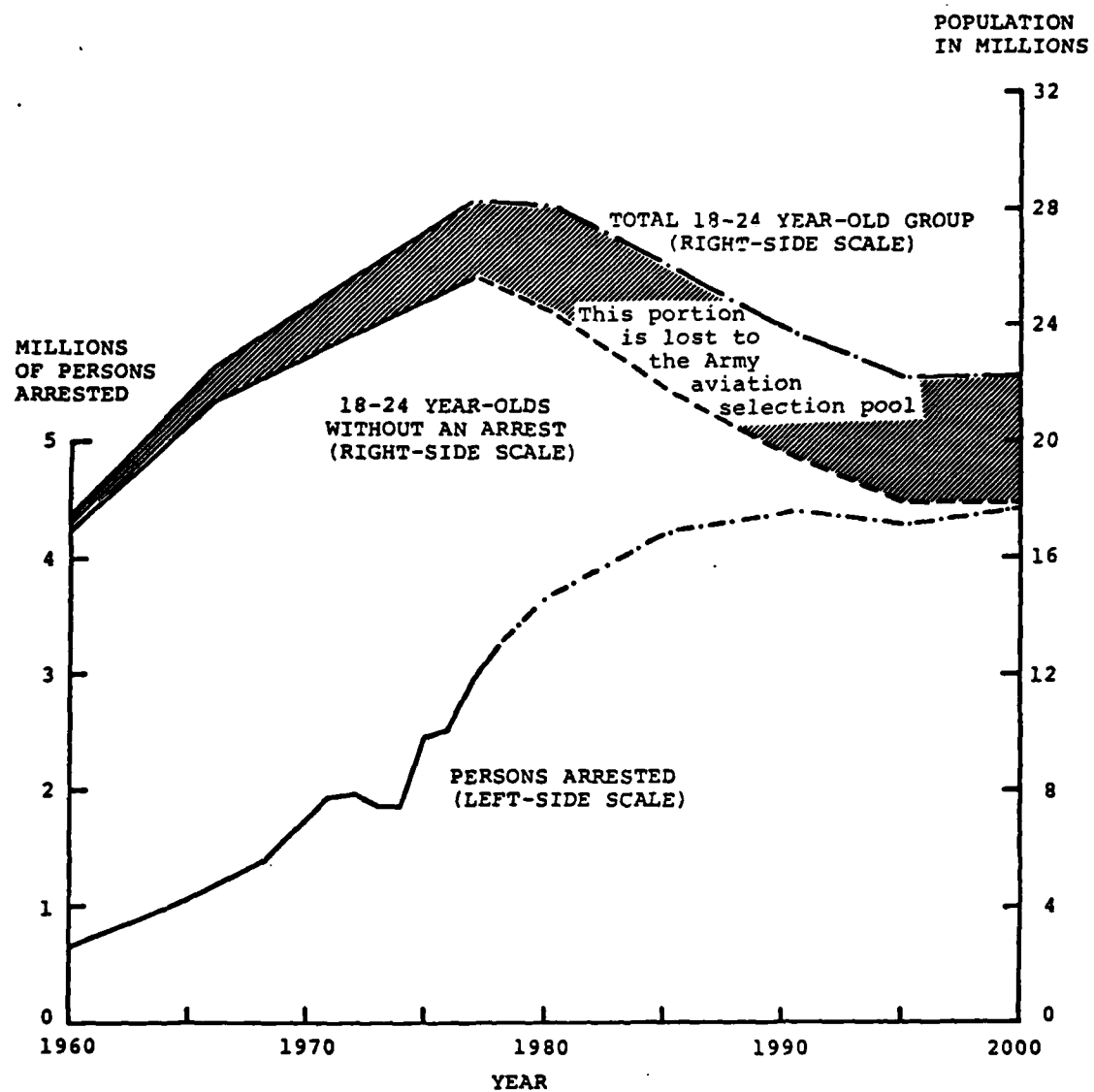


Figure 7. Arrest Trends in 18-24 Year-old Age Group.

PERCENT OF
PERSONS ARRESTED

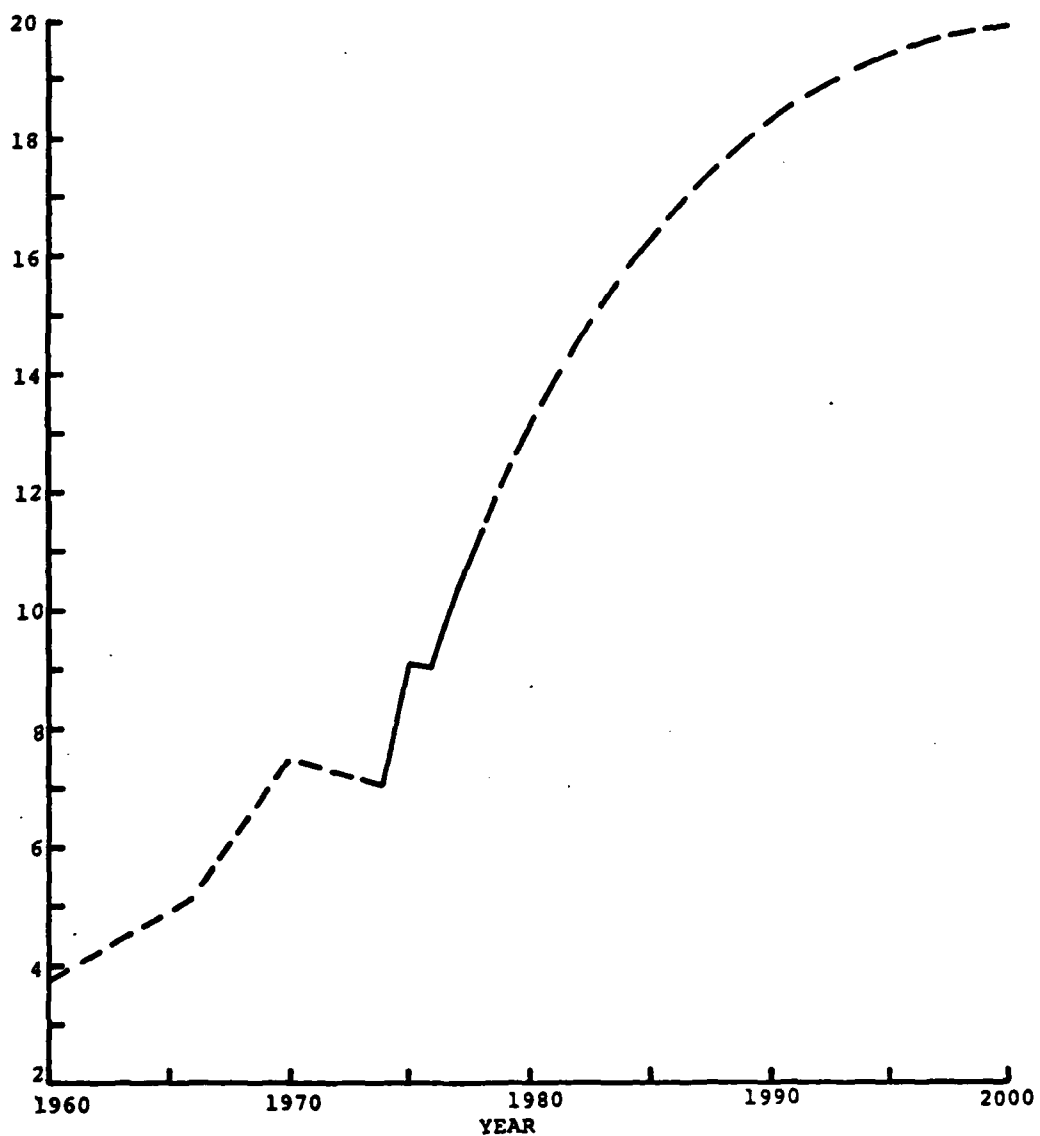


Figure 8. Percentage of 18-24 Year-old Age Group Arrested.

strong upward trend seems likely in view of juvenile attitudes, but that societal pressures will ultimately halt the increase when one out of every five persons in the 18 to 24 year-old group has an arrest record. This rationale is an assertion, not supported by research. The effects of this projection on the number of persons arrested and on the number of persons without an arrest are shown in Figure 7. It may be noted from this figure that the shrinking future personnel pool will be reduced even further by the subtraction of those with arrest records. This decrease is only partially additive to the decreases resulting from failure to complete high school, since a substantial portion of the arrests will come from the high school dropout category.

Other factors are obviously of importance in determining probability rates of Army accessions, and further study of all factors of significance would be warranted. However, such further study would be considerably beyond the originally-intended scope of the research reported in this study. The assessments of Army aviation personnel availability given in Sections 7.2.1 and 7.2.2 are believed to be useful in delineating some of personnel factors which must be considered in connection with helicopter pilot training in the 1980s decade.

SECTION 9 REVIEW OF THE LITERATURE

The literature review was conducted in accordance with the approach described in Section 2.4. In this section, brief statements concerning the contents of relevant items of this literature are presented. The organization of subjects follows the categorization in Section 2.4, which was organized to facilitate identification of training topics for which information is limited or non-existent. Each item of literature which is mentioned in this review is identified by author and date. Therefore, numbered references to the bibliography at the end of this section have not been provided in the text. The bibliography is arranged in the same sequence as the discussion.

This literature review was used primarily as background for the analysis efforts described in this report. The synopses of the literature that are in this section provide a useful description of the current level of knowledge in the areas discussed.

9.1 PRETRAINING VARIABLES

Pretraining variables are factors which logically and temporally precede the development of training programs. These factors included performance requirements, performance measurements, and trainee selection. Performance requirements are the tasks and operations for which students are trained. Performance measurement is the establishment of standards for determining successful accomplishment of these tasks and operations. Finally, the selection of trainees was considered.

9.1.1 Performance Requirements

Because of its present and future importance for Army aviation, instrument flight was treated as a major subcategory of performance requirements. First, general aircraft operations were considered. Besides the topic of general aircraft control, special attention was paid to approach landing, hovering, and tracking tasks. Because of the Army's mission, special attention also was paid to nap-of-the-earth (NOE), night, and adverse weather flight and combat operations.

Little research was found concerning general flight skills and procedures. Rather, most research has focused on problematic aspects of flight. A few exceptions to this trend were noted. Atkinson and Whitfield (1972) described problems in controlling hovercraft and compared pilot and non-pilot performances in hovercraft control. The Coast Guard conducted a comprehensive study of aviator requirements during operational missions (Hall, et al., 1969). Siegel and Federman (1973) investigated the relationship between helicopter team performance and the content and flow of communications. Criteria for handling qualities of helicopters have been developed using pilot evaluations (Advisory Group for Aerospace Research and Development, Paris, no date).

Research on the handling qualities of aircraft may lead to studies of pilot performance requirements. Alansky, et al. (1977a and 1977b) and Kesler, et al. (1974) studied handling qualities of helicopters carrying

external loads. Wilcock (1976) investigated the general handling qualities of a specific helicopter, and Etzel, et al. (1971) reported the performances of a specific helicopter in the Arctic environment. Waugh and Stephens (1976) studied human energy expenditure in specific helicopter control.

Problems of helicopter pilot disorientation were investigated by Hixson, et al. (1972), Ogden, et al. (1969) and Tormes and Guedry (1974). Stave (1977) studied the effects of noise, vibration, and fatigue on helicopter pilot performance. Finally, McDaniel (1978) studied antitorque system failure and Kurylowich (1979) developed a method to study problems created by vortical wake.

Compared to the topics just reviewed, the topic of approach-landing has received more attention. Most research in this area has focused on the evaluation of various instruments and displays and various combinations of them (Clement and Hofmann, 1969; Hindson and Smith, 1976; Kelly, et al., 1974; Lebacqz, 1979; Lewis and Mertens, 1979; Niessen, et al., 1977; Wingert, 1974; Wolf, 1970). In addition, Hindson and Smith (1976) and Lebacqz (1979) studied approach-landing under adverse meteorological conditions. Another area which has received special attention is aircraft control during hovering. Once again, the work has focused on evaluations of instruments and displays (Bynum, et al., 1974; Duffy, 1976; Hoxie, 1974; Fetzer, 1977; Millelli and O'Connor, 1970). Two of these studies (Bynum, et al., 1974; Hoxie, 1974) included investigation of visual perception as a major feature of the research.

A third area in which relatively more research has been conducted is tracking. This area includes perceptions other than those of instruments and displays--usually perceptions of objects exterior to the aircraft--and judgments resulting from these perceptions. Armstrong, et al. (1975) studied altitude and ground speed judgments of Army aviators. Malcolm and Jones (1973 and 1974) examined the reliability of subjective response to vertical linear accelerations in the absence of vision. Bynum, et al. (1973) investigated aviator perception and hover control in terms of a fixed referent placed on the helicopter windscreen and an external referent placed on the ground plane. Crowder, et al. (1975) indicated that improved hover accuracy is obtained when a helicopter pilot uses an eye-line-of-regard depressed substantially below his customary visual scan pattern. Hoffmann and Buell (1976) studied detection of beacons from an approaching helicopter. Various literature (Advisory Group for Aerospace Research and Development, Paris, 1972 and 1975; Pabon, et al., 1976; Warnick, et al., 1979) dealt with tracking tasks related to operations under battle conditions. Finally, there is a body of literature (Ozkaptan, 1978; Shipley, 1979; Simmons, et al., 1976; and Stern, 1972) which deals with methodological issues related to the study of visual activity.

Because of its importance for Army aviation tactics, NOE flight has been the focus of much investigation. Cox and Giessler (1978) empirically established NOE flight mission profiles, Kimball, et al. (1974) studied pilot performance and aircraft state during NOE flight, and Lewis, et al. (1968) compared navigation effectiveness during NOE flight of solo pilots and a pilot-navigator team. Much of the study of NOE flight has been directly related to training. Gainer and Sullivan (1976a) developed training objectives based on analysis of mission requirements and aircrew tasks. Based

upon the results of experimental research, Fineberg, et al. (1976) suggested improvements in work methods and training. Harman (1978) evaluated the Beseller cue/see method for navigation training for NOE flight. Farrell and Fineberg (1976) studied transfer of skills to NOE flight and special training for NOE flight. Gainer and Sullivan (1976b and 1976c) defined aircrew training requirements for NOE flight. Erwin (1979) examined the issue of fidelity in simulation of NOE flight. Finally, Roscoe (1976) reviewed the state of the art of aircrew training technology for NOE flight.

Closely related to NOE flight are issues of flight at night and during adverse weather. Recently, a symposium on helicopter flight at night and in poor visibility was held (Howell, 1979). Instrument and display requirements for night flight have been investigated and instruments and displays have been evaluated (Army Electronics Command, Fort Monmouth, NJ, 1974; Kleider, 1975; Anderson and Toivanen, 1972). Of special interest is the development and evaluation of night vision goggles (Lees, et al., 1976; Wiley, et al., 1976; Stone, et al., 1979). Isgrid and Best (1973) evaluated training requirements and performance expectations for night tactical operations by attack helicopter teams.

Issues that have been studied that are related to battle conditions are diverse. These issues range from the study of psychological variables (Boyles, 1968) to the study of evasive maneuvers by helicopters (Houck, et al., 1976) to the study of target acquisition (Ton, et al., 1979). Of special note is an evaluation of tactical training of Marine Corps attack helicopter pilots (Ross, 1977).

Performance during instrument flight was given special consideration in this review because of its present importance in helicopter flight and its probable increasing importance in future Army aviation. Most of the literature in this area has dealt with evaluation of various displays and display configurations and augmentations (e.g., Air Force Instrument Flight Center, Randolph AFB, Texas, 1977; Boivin, et al., 1973; and Hasbrook, et al., 1975). Some of this literature has related specifically to equipment used in Army aviation (e.g., Anderson and Hollingsworth, 1972; Hofmann and Frezell, 1977; and Toivanen, et al., 1971). Gilson and Fenton (1974) and Triggs et al., (1974) compared tactual and visual displays. Morrow (1970), Maruyama (no date), and Stonwell and Poston (1974) discussed optimization of lighting in the helicopter cockpit. Buckler (1978a and 1978b) has reviewed the literature on electro-optical flight displays with emphasis on rotary-wing aircraft. He concluded that literature pertaining to the experimental comparison of displays with different symbology formats was, for the most part, sorely lacking.

There is a limited body of literature dealing with general issues related to instrument flight. Some of this literature reports on the study of techniques employed by pilots for gathering information from displays and discusses the information that was actually gathered and used (Barnes, 1970; Demaio, et al., 1976; Frezell, et al., 1973 and 1975; and Harris, 1979). Other literature reported on the study of the effects of display variables on pilot workload and performance, especially under objectively and psychologically adverse conditions (Baron and Levison, 1975; Callan, et al., 1974; Demail, et al., 1978). The problems of the cockpit environment were the

subject of an international conference (Advisory Group for Aerospace Research and Development, Paris, 1970), and a bibliography concerning human factors in the design and control of aircraft has been assembled (Defense Documentation Center, Alexandria, VA, 1971). Methods for studying pilot opinions and judgment regarding controls and displays in helicopters has been suggested (Armstrong, et al., 1975) as have procedures for design of control and display systems (Curry, et al., 1977; and Wright, 1970).

9.1.2 Performance Measurement

Performance measurement concerns the techniques for rating task accomplishment. Performance measurement is important for establishing performance criteria which become training objectives and in light of which the success of training is determined. The review disclosed very little literature which fits uniquely into this category. Billings, et al., (1973) presented data which indicated that engine RPM variability is a valid index of helicopter pilot skill. Prophet (1972) reviewed 15 years of research by the Human Resources Research Organization on measurement techniques of flight performance of helicopter trainees and pilots. Boyles and Wahlberg (1971) discussed the development of a multivariate prediction system to determine the potential of Army aviation trainees. Barnes and Statham (1970a and 1970b) described initial research for the establishment of normative data for pilot performance in all Army helicopters.

9.1.3 Trainee Selection

Literature was reviewed which relates to two trainee selection issues. First, literature was reviewed which addressed the population pool from which the military can recruit. The most recent work in this area has been done by Fernandez (1979 and 1980). Second, literature concerning selection methods and instruments was reviewed. Kaplan (1968) evaluated the Army fixed-wing aptitude battery in selection for ROTC flight training. Eastman and McMullen (1978a) evaluated the predictive validity of the Flight Aptitude Selection Tests (FAST). They also suggested a shorter version of FAST (Eastman and McMullen, 1978b). Marco, et al. (1979) evaluated the Air Force's Proficiency-Based Aviation Selection System (PASS) for rotary-wing pilot trainee selection. Murdoch (1977) and Pettyjohn, et al. (1977) discussed medical criteria for aircrew selection.

9.2 TRAINING TECHNIQUES AND TECHNOLOGY

9.2.1 Adaptive Training and Computer Aided Instructions

General reviews related to adaptive training techniques for military aviation and to computer aided instruction (CAI) in military training are available. McGarth and Harris (1971) summarized the results of a conference on adaptive training for Army helicopter pilots. Sherron (1975) summarized computer aided instruction at 24 military installations in the United States. Also, Crawford, et al. (1970) reviewed CAI in the military. Feurzeig-Wallace (1971) discussed a computer based instructional system for aviation training. Caro (1970) discussed the Synthetic Flight Training System.

9.2.2 Simulation and Simulators

A relatively large body of literature dealing with simulation and simulators exists. The National Technical Information Service (NTIS) has documented and periodically updated a two volume bibliography describing flight training of Army, Navy, and Air Force airmen by the use of simulators and simulation systems (Adams, 1977a, 1977b; and Habercom, 1980). A separate NTIS bibliography covers design and development of the simulators. Brown (1975) and Caro (1977a, 1977b) have expressed need for research in the specific areas of techniques for simulation of the visual world, sources of visual information, electronically generated displays, dimensions of the visual display, motion simulation, and criteria for the evaluation of simulators as well as the general area of more efficient training equipment.

A number of publications (e.g., Conklin, et al., 1968; and Diehl and Ryan, 1977) describe the experiences of the airline industry and the military in reducing flying hours by introducing new or additional simulator training. The fuel shortage and comprehensive simulator experience used by NASA in the Apollo and Space Shuttle programs have contributed to increasing use of this concept.

Toomepuu (1976) has discussed Army flight simulator programs from the user's viewpoint. User evaluation of the quality and suitability of Army flight simulator programs, cost effectiveness of flight simulators, and research initiatives needed to meet Army aviation training needs were addressed.

Pester (1979) reported on the formulation of a digital data base to produce Computer Generated Imagery (CGI) of terrain scene data utilized to train pilots.

Shaughnesy, et al. (1979) reported the development of a mathematical model and proposed piloted simulation of a helicopter and external sling load. A visual landing display system for use in the simulation was described.

The Navy reported (Wilson and Vanderhorn, 1967; Woomer and Corico, 1977) on a program to increase flight fidelity of helicopter simulation. Extensive tables of criteria data tests are provided for reference. The Navy also reported investigation of three-degree of freedom helicopter motion base drive techniques in 1978.

Several publications (CAE Electronics, 1977a, 1977b; and Dickman, et al., 1977) described the development of simulation for the Army Attack Helicopter (AH-64). Development of simulation for the UH-1 helicopter is reported by Hennessy, et al. (1979). Sinacori (1970) suggested guidelines to be used in developing mathematical vehicular representation to simulate helicopter flight with the Northrop rotational simulator. Several Navy publications (Thomas and Jones, 1979; Yeend and Carico, 1978) discussed field of view cockpit display considerations applicable to helicopter simulation.

Several publications (e.g., Caro, et al., 1973; Holman, 1979; and Miller, 1976) have dealt with evaluation of helicopter simulators as flight training devices. Cost effectiveness is addressed in a number of publications (Army Aviation Center, Fort Rucker, AL., 1976; Army Training and

Doctrine Command, Fort Monroe, VA, 1977). Caro (1977a, 1977b) addressed current problems. He concluded that simulator training must be viewed as a part of the larger training system and not as an independent element.

Bynum (1978a) reported an evaluation of the Singer Computer Generated Image Night Visual System attached to the UH-1 flight simulator. Recommendations were made for alterations and further tests. The Army has sponsored evaluation of helicopter simulators used for instrument flight training and basic flight training in the late 1960s and early 1970s (Prophet and Caro, 1974). There were also studies (e.g., Jolley and Caro, 1970) of the economics of using simulators for flight training during this same period.

Bynum (1978b) and Welp, et al. (1975) addressed design and evaluation of Nap-of-the-Earth Trainers for use by the Army. A few publications discussed training aircraft, simulators, and subsystem trainers using computer generated imagery (Army Aviation Test Board, Fort Rucker, AL, 1967; Herald, 1977).

General discussion of the suitability of various aircraft and helicopter simulators for instrument training was the topic of several publications (e.g., Army Aviation Test Board, Fort Rucker, AL, 1964a, 1964b, 1964c, 1964d; and Davis and Comer, 1963).

9.3 UNDERGRADUATE TRAINING

Most of the literature which has focused uniquely on undergraduate training has considered either the economics of training or the evaluation of student pilots. Allison (1969) proposed a model for the Air Force to estimate the resource requirements and attendant costs of undergraduate pilot training. Cook (1969) analyzed the costs of Air Force pilot training. Zilioli (1971) studied the costs of training and maintaining an Army aviator in relation to crash injuries and fatalities. McCauley and Bradley (1976) analyzed a proposal to consolidate all Department of Defense undergraduate pilot training.

Caro (1968) compared several methods for evaluating Army student pilot performance. Childs (1979) reported a test of two inflight scoring procedures. Dees and Dufilho (1975a) reported procedures for predicting performance of Army aviator trainees. Finally, Elliot, et al. (1979) suggested a study of attrition in the Army's initial rotary wing training program.

Other literature on undergraduate training has dealt with an innovative instrument flight training program (Caro, 1971) and Navy training situation analysis. Prophet (1978) reviewed Navy flight training, and Groves and Shelburne (1967) reviewed education in the armed forces.

9.4 POST GRADUATE ISSUES

Advanced pilot training in the Army was reviewed by Kennedy (1969). Mooz (1969) studied the career flow of pilots in the Air Force. Apart from these general studies, literature has addressed three issues. First, Smith and Matheny (1976a and 1976b) and Wright (1973a and 1973b) addressed issues of retention and refresher training. Second, Barnes (1970) and Caro (1970)

addressed the issue of transfer of training. Finally, three studies (Ciley and Long, 1979; Isley, et al., 1979; and Long, et al., 1979) addressed pilot training at the unit level.

9.5 OTHER TRAINING RELATED LITERATURE

A large part of the other literature reviewed consisted either of conference proceedings or summary reports. This literature included proceedings of an Army aviation instructors' conference (Army Aviation School, Fort Rucker, AL, 1968), a conference on advanced rotorcraft (Advisory Group for Aerospace Research and Development, Paris, 1973), a conference on air crew performance in Army aviation (Deputy Chief of Staff for Research Development and Acquisition-Army, Washington D.C., 1973), and a conference on education and training in the Department of Defense (Davenport, et al., 1966). Summary literature included annual progress reports of the Army Aeromedical Research Laboratory (Bailey, 1975 and 1976), a review of Department of Defense training research and evaluation for FY 1977 (Orlansky, 1977), and summaries of training research and development conducted by the Human Resources Research organization (1969 and 1970; and Lavisky, 1969). Other literature to be noted included a study of the Army aviation warrant officer program (Army Military Personnel Center, Alexandria, VA, 1977), a study of the Coast Guard's aviation synthetic training programs (Isley, et al., 1974), and studies of Navy helicopter pilot training programs (Gibbons and Hynes, 1978; Hearold, et al., 1979).

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SECTION 10

IDENTIFICATION OF REQUIREMENTS FOR BEHAVIORAL RESEARCH

Three behavioral research requirements for future Army aviation aircrew training were identified. The first is the need for expansion or follow-up of earlier studies. The issues examined in earlier studies are frequently dynamic in nature and may change over time. A pattern of different results and conclusions, reflecting changing characteristics of future aviation systems/subsystems and operational environments, may be expected to require updated research. The second behavioral research requirement concerns potential new missions which may become possible because of advances in aviation system/subsystem capability, or new missions which may become necessary because of new operational environments. The third behavioral research requirement is connected with training tasks which are affected by significant changes in the characteristics and capabilities of aviation systems or subsystems.

Various extensive research efforts have been conducted concerning some of the topics discussed below. However, much of the literature reported the findings of isolated projects concerned with specific problems. For example, there is an extensive body of literature on the general area of display perception, decision making, and instrument flight. Much of the literature in this area resulted from the need for evaluation of specific displays and/or combinations of displays. The intent of these studies, quite rightfully, was not to examine the basic principles of human cognition, information processing, and performance, even as they related to helicopter operations. However, some of this literature may contain information which increases the knowledge of basic behavioral principles as they relate to Army aviation. For those topics which are covered relatively extensively in the literature, the first step in future research should be a "state-of-knowledge" literature review. For example, such a literature review could answer the question "at does research evaluating various displays and display configurations tell us about cognition, information processing, and performance as they relate to Army aviation?" "State-of-knowledge" literature reviews would decrease the probability that future research would duplicate already existing knowledge and would help specify the need for particular research projects.

10.1 EXPANSION OF FOLLOW-UP STUDIES OF EARLIER BEHAVIORAL RESEARCH

Various research issues investigated in Army aviation aircrew behavioral research in the past two decades are still of great importance and interest to future Army aviation. The effectiveness of training innovations, the usage of simulators in future training, flight skill retention, requirements for undergraduate and postgraduate pilot training, and manpower analysis should continue to be investigated to support the development of effective aircrew training programs.

10.1.1 Training Innovations

Innovations such as automatically adaptive training, computer-assisted instruction, adaptive measurement of residual attention, automatic performance measurement, cinematic simulation, and interactive computer-

control display devices have been reviewed by Roscoe.[35] Developments on some of these training innovations could be improved. Evaluation of the effectiveness of using these and other training innovations will provide valuable information in the selection of approaches and procedures in future Army aviation aircrew training. Effectiveness can be examined in relation to training objectives over different behavioral categories such as procedural activities, decision-making activities, and perceptual-motor activities.

10.1.2 Simulator Training

Although the literature review revealed what appears to be a plethora of research on the use and effectiveness of simulators for helicopter aircrew training, the importance of this topic clearly requires additional research and more definitive results. It is now accepted that simulator training is more cost-effective than flight training, up to a point. However, that point is not yet clearly defined. Controlled experiments, comparing objectively measured performance of crews undergoing differing amounts of training time in simulators versus actual flying, are essential to determine optimum amounts of each, with due regard to total cost differentials of each type of training. To the extent that performance must be judged qualitatively, it would be highly desirable for the judges to be unaware of the differences in training experienced by the crews.

Two important factors do not appear to have been adequately evaluated by prior research. The first is the perception of the trainees themselves of the relative degree of competence attained through various mixes of simulator versus flying time. For example, even if an objective evaluation should indicate that the highest competence would be obtained without any actual flight time, the trainees might well lack confidence in their ability to perform in the air. Research on crew perceptions of degree of confidence achieved through simulator training can be achieved at little, if any, additional operational cost through well-constructed surveys of such perceptions at various intervals in the on-going training process.

The second factor is the psychological need of aircrew personnel for actual flying. First and foremost, all aircrew personnel want to fly. They will accept and even welcome simulator training to the extent that they perceive it will help them to do a better job in the air. However, because their primary goal is air time, any interference with that goal will be resented. Motivational research is needed to define minimal and optimal amounts of flying time required by aircrews to ensure their retention as Army helicopter pilots. It is evident that both of these factors have been involved in determining amounts and types of training by simulations versus actual flying. However, these two factors have been hidden or unacknowledged, and in any event could not receive adequate consideration because of the lack of knowledge of their effects.

10.1.3 Flight Skill Retention

Behavioral research will be required in the analysis of aircrew flight skill retention. Findings from earlier flight skill retention studies may still be applicable to new aviation system/subsystem training. However, answers to questions on skill retention of flight tasks involved in night nap-of-the-earth, air-to-air combat, or rapid deployment assignment are not available.

10.1.4 Undergraduate/Postgraduate Training Syllabi

Hours and content of undergraduate pilot training and postgraduate unit training need to be determined. System/subsystem capability improvement may make certain flight tasks easier and consequently, fewer hours will be required in training for these tasks. On the other hand, new flight tasks introduced by system/subsystem capability improvement may require more time in pilot training. Hours and approaches in unit training, to maintain pilot combat readiness, may be significantly different from current Army aviation practices. In other words, research efforts are needed to determine the best strategy for undergraduate pilot development and for the maintenance of unit pilot combat readiness.

10.1.5 Personnel Availability and Qualifications

The demand for, and supply of, manpower has been a continuing consideration in Army training programs. Numbers and qualifications of aviators should be defined in accordance with Army aviation operational plans. Complete manpower demand projections reflecting future Army plans as well as future aviation system/subsystem characteristics should be prepared. The supply of potential Army aviators in the future may be influenced by economic conditions, educational trends, and general youth population trends. Recruitment difficulties and measures to alleviate these difficulties should be examined to ensure that a sufficient number of qualified Army aviators will be available in the future. More relevant military manpower supply projections should be developed (as was discussed in Section 7.2).

10.1.6 Integration of Sensory Inputs

Although research has been conducted on auditory and tactile sensory inputs over the years, practical applications seem to have been limited to rather simple warning items such as bells, buzzers, voice tapes, and stick shakers. Little research appears to exist on optimum balance of sensory inputs or on saturation limits for multiple stimuli. Intuitively, it would appear that visual inputs should be limited to external situations or replicas thereof, with warning information given by auditory or tactile means. The increasing use of HUD displays is evidence of the need for visual emphasis on the external situation. Warning information should require a minimum of pilot interpretation to elicit the correct response. For example, a voice signal to "break left" is much more useful than a red light whose meaning must be interpreted in terms of its location on a panel, or a buzzer whose tone must be decoded by the pilot. The examples indicate the nature of possible payoffs in system design through behavioral research on optimum integration of sensory inputs.

10.1.7 Crew Behavior in the Region of Workload Saturation

In addition to the prior and on-going research directed toward determination and alleviation of aircrew workload, some particular topics could be usefully emphasized because of the changing demands of the newer Army aviation systems. The first of such topics is the examination of crew behavior as the limits of workload saturation are approached, reached, and exceeded. Saturation of information processing capability and of action sequence response capability may occur separately or concurrently. In the first case the subject becomes confused and cannot formulate any course of

action. In the second case the subject may know what sequence of action is required, but is unable to execute that sequence in the time available.

Simulators can be used to conduct research on both of these problems safely and realistically for situations of direct interest to Army aviation training. In addition to producing a basic understanding of these problems, further goals should include development of ways to establish "graceful degradation" of crew performance rather than "catastrophic failure," as stress limits are reached. "Escape routes" and "fail-safe" modes should be established for crew performance so that crews may recover to an unsaturated mode without losing fundamental operational capability, e.g., control of the aircraft. This research should also include further studies of patterns, causes, and symptoms of workload saturation and catastrophic failure.

10.1.8 Comparative Losses From Enemy Fire vs. Ground Impact

Operations research is required to provide specific information on probable loss rates from enemy fire and from ground environment impact at various altitudes and speeds, for various levels of enemy threat, and for differing terrain conditions. This information should be provided to commanders and aircrews in easily understandable form for operational use. One such form might be a graphical presentation of the curve of combined loss rate from enemy fire and ground environment impact per 100 missions, versus the parameter of speed divided by altitude. A curve of this type for a given threat level and ground environment class would be saddle-shaped with a low point indicating the optimum speed/altitude for minimum combined losses. A small set of such graphs for various levels of enemy defense and classes of ground environment, for both day and night, would provide a useful guide for combat operations.

Early availability of such an aid, even though approximate, would be much better than waiting for the ultimate, finely detailed, and absolutely accurate analysis which is also probably unattainable. Such a solution is also infinitely preferable to the current dictum to "fly as low and as fast as you can." This dictum is an insufficient criterion because no single speed/altitude trade-off between enemy threat and ground environment impact exists. Even better than graphical presentation (once the concept was made clear in training) would be an equivalent simple program for the cockpit computer. The crew could enter input data on expected enemy threat level and ground environment type and receive output information on the optimum speed/altitude combination. Updating, based on encountering differing conditions, could be accomplished almost instantly. Although much research on NOE operations has been conducted, nothing of the sort described above was discovered in the literature search.

10.1.9 Aircrew Performance in Adverse Environments

The 1973 Conference on Aircrew Performance in Army Aviation recommended that "systematic field tests (be conducted) to provide quantitative assessments of aircrew performance under these (precipitation, limited visibility, wind, snow-covered terrain) conditions." [36] To the extent that this work remains undone or incomplete, simulation capabilities now provide a much better research approach. Current computer-imaging capabilities, which should be available in regular crew training simulators,

may be programmed to replicate any of the conditions indicated above. Crew response, operational problems, and training requirements associated with these conditions can be determined under controlled conditions, at much less cost than by field tests. Testing under actual field conditions could be limited to verification of simulator-based research and could be explicitly directed toward known problem areas, rather than being used in the problem-search mode which tends to be a wasteful, high cost research approach.

10.1.10 Reversal of Visual/Instrument Flight Training Sequence

The difficulties experienced in instrument flying, both in fixed-wing aircraft and helicopters, combined with the training opportunities now possible with advanced simulators, suggest that research on a new approach to flying training might provide a substantial pay-off. This approach would reverse the present sequence of teaching visual contact flying first, followed by instrument flight training, during which many responses taught in the visual phase must be unlearned. The presumed advantages of reversal derive from the following observations. First, a persistent error in instrument flying is the tendency to disbelieve the instruments, traceable to the sequence which implies that instrument flight is secondary to "real" flying. Second, a common attitude is that flight based on instrument cues is difficult, which is also traceable to the sequence which implies that instrument flight is "unnatural."

Those whose aptitude for instrument flight is poor could be eliminated early in the program, prior to large investment in visual flight training. This is particularly important in view of the fact that most "wash outs" occur during instrument training, which is considered the most difficult part of the syllabus. The capabilities and cost of simulators are now such that very effective instrument-flight training can be provided as the first step in training at a much lower cost than visual flight in actual aircraft. Behavioral research is needed, using control groups, to evaluate the relative effectiveness of the two sequences. This research would be quite pragmatic and would incur very little additional cost since it could use existing syllabi except for changes in sequence. This approach might also be extended to examination of a sequence in which instrument flight simulator training is first, followed by night flight simulator training, with visual contact flight training last.

10.2 BEHAVIORAL RESEARCH IN RESPONSE TO NEW MISSION OR OPERATIONAL ENVIRONMENTS

Night nap-of-the-earth, air-to-air combat, and rapid deployment activities will become more common in future Army aviation operations. Detailed flight task requirement analyses of these missions are required for the development of mission plans and training programs. Studies similar to the one describing the aircrew training requirements for nap-of-the-earth flight by Gainer and Sullivan [37] may be the first step in analyzing night nap-of-the-earth air-to-air combat requirements. Those studies will establish training objectives and define flight tasks. Training doctrine for these flight missions must be developed before any appropriate training method can be analyzed and adopted.

10.2.1 Rapid Deployment Mission Requirements

Battlefield management, mission planning, navigation, and crew coordination will receive much more attention in the preparation of Army aircrews for future rapid deployment missions. Unfamiliar and adverse weather conditions as well as drastically different terrain can be expected in joint forces rapid deployment operations. This points out the need to develop adverse weather and different terrain training modules to provide effective training for the Army aircrews who will participate in rapid deployment assignments in trouble spots around the world. Of course, the effectiveness of these training modules should be evaluated first. Related behavioral research would include the examination of flight skill retention by Army aviators assigned to the rapid deployment task forces.

10.2.2 Night Flight Operations

Research is needed to identify both the physical and psychological attributes which are important in night-time flight operations. Once the attributes are known, further study will be required to determine appropriate selection techniques, and to define the type of training needed to enhance or better utilize those attributes. This research could also support decisions on whether to exclude from helicopter training those individuals who are poorly qualified for night operations, or whether to establish separate squadrons for day and for night operations. A precedent for the latter approach may be found in the following quote relating to German development of night-fighter capability during World War II. "Exercises in night fighting served to reemphasize the dependence of night fighter attack on individual pilot ability." [38] Throughout the war, Germany maintained special night fighter forces, and pilots assigned to night fighter duties remained in those forces and did not ordinarily return to day fighter duties.

Another aspect of night operations related to training activities is the determination of the essential cues used by the aircrew in night operations. These cues may be replicated more easily by computer-generated image systems in dusk-and-night-only simulators than by the large terrain model boards with movable optic probes used in day-operation simulators. The computer-generated image systems are also infinitely more flexible than the terrain model boards. Therefore research aimed at determining the cues which are most important in night operations could have a very significant pay-off. Early research by James A. Bynum provides a basis for further research in this area. [39]

10.2.3 Air-to-Air Combat Requirements

Behavioral research for air-to-air combat should be conducted concurrently with the development of doctrine and tactics for this mission. A key issue will be the detection and identification of attacking enemy aircraft at long ranges, both visually and electronically. An important area for study will be the identification of the types of cues which enable early detection of an enemy air threat even though the aircrew members are concentrating on their primary mission in a high ground threat environment.

Another important factor will be determination of the amount and type of simulator training required to enhance pilots' chances of survival and victory in their first decisive encounter. Studies of fixed-wing air combat

have indicated that pilot survival chances increase rapidly in each successive encounter and that the first encounter is critical. Simulation techniques and criteria should be developed which will select those pilots with the greatest aptitude for air-to-air combat and provide training so that they will enter their first actual combat with the equivalent of many combat encounters behind them.

When doctrine, tactics, roles, and missions have been defined for helicopter air combat, then research may be required with respect to motivation and discipline for the crews assigned for the various roles. For example, if the psychological rewards for aerial victories are disproportionate to those for ground attack, there will be a tendency for the aircrews to break off from primary attack missions to pursue enemy helicopters. The scarcity of literature references on air-to-air helicopter combat emphasizes both the need and opportunity for research related to this topic.

10.2.4 Nap-of-the Earth Operations

Almost all of the research on NOE operations implicitly assumes the existence of terrain and/or vegetation conditions which can provide concealment in very low level flight. This is natural and consistent with experience in Vietnam, conditions in Western Europe, and training opportunities around Fort Rucker. Research is needed on the applicability and adjustment of NOE operations to combat in flat, treeless terrain. Differences in tactics, and use of substitutes for tree and terrain cover, such as smoke screens, radar jamming, and suppressive fire by fixed-wing close-air-support, will require additional types of training, which must be preceded by research to determine the behavioral actions appropriate to these changes.

During the original literature review no reference was found on NOE operations which dealt with the issue of helicopter operation in city areas, which have many similarities and many differences from natural terrain. However, it was subsequently found that work in this area has been accomplished by the Navy and has been reported in O. A. Larson, et al., "Urban Area Combat Training: Aviation Implications," NPRDC SR-81-11, February 1981. Fire from concealed positions in built-up areas may provide the same danger to helicopters as that from wooded positions, while providing much more protection for the enemy. Buildings in cities have the same potential for helicopter concealment and for hazards to flying as trees in natural terrain, but obviously cannot be treated identically in developing tactics and procedures. Because of the likelihood that some future operations will require combat in metropolitan areas, research should be conducted on the problems associated with such operations.

10.2.5 Helicopter Formation Flying Requirements

The literature review did not indicate the existence of significant research on problems of tactical formation flying with helicopters. High threat situations, massed enemy armor, and air attacks by enemy helicopters may well require more use of close-formation helicopter tactics than has been experienced previously. Research on the concentration, near-field distance perception, and flying skills required for close-formation helicopter flight under combat stress would provide for development of

training methods which would not expose crews and aircraft to collision losses until a high degree of competency has been developed.

10.3 BEHAVIORAL RESEARCH REQUIREMENTS ARISING FROM AVIATION SYSTEM/SUBSYSTEM CAPABILITY IMPROVEMENTS

Future Army aviation systems/subsystems may decrease aircrew workload on certain flight tasks and/or introduce additional tasks which increase aircrew workload. In general, aircraft manufacturers include aircrew workload analysis in their design processes. Workload analysis data aid human factors engineers in crew station design. For aircrew training, workload analysis is needed in the assignment of flight tasks to aircrew members and the examination of crew activity coordination. Multiple activity charts of crew members and time-line analysis of tasks should be prepared. Updated analyses are required whenever product improvement programs take effect. Appropriate methods of defining or measuring workload may have to be developed before workload analyses on certain flight tasks can be conducted.

10.3.1 Information Processing

The introduction of more advanced avionic equipment in helicopters makes the Army aviator part of an information processing system. Effective uses of computers and decision support facilities become essential to aviators. Information processing functions affect a wide range of flight tasks; e.g., navigation; communication; weapon aiming; battlefield management; and control, command, and communication. Behavioral research is needed to identify aviator aptitude for information processing and decision-making activities. The standard for selecting aviator candidates should be reviewed. This may also lead to the redesign of aircrew candidate aptitude tests.

10.3.2 CRT Displays

Very advanced behavioral research will be needed to determine the optimum cuing systems for CRT displays. An important aspect of this determination will be the use of subjects who do not have prior experience with any current cockpit instrumentation. This will require a very basic approach in defining each of the aircrew tasks to be performed, followed by experimentation with various types of cues for each task to determine which cues and cuing sequences result in the fastest and most accurate responses. This research will result in revolutionary recommendations for display systems. In particular the findings will call for major departures from current displays which are strongly biased by pilot familiarity with the information provided by now obsolete instrument systems. Thus a part of the research must be directed toward methods of diminishing experienced-pilot resistance to advanced information displays. Research will also be required to define the type and amount of retraining which will be required for pilot accommodation to unfamiliar displays. If the above approach is not taken, the opportunities for exploitation of the full potential of CRT displays will be long delayed. The literature search did not reveal a large amount of research relating piloting requirements with CRT-provided information, and no articles were discovered which dealt directly with the above issues.

10.3.3 Tactile Skills

Automation of systems and training devices is emphasizing the importance of tactile skills in system operation. Basic "keyboard" aptitude is of growing importance, and is of particular importance for machine controlled training. Information on techniques for measuring tactile ability is available in the general literature. This should provide a basis for further work to determine tactile aptitude testing procedures and to establish design criteria for automation in Army aviation systems and teaching machines.

10.3.4 Training Feedback to Machine Design

Generally speaking, training requirements are assumed to be based upon the predetermined characteristics of machines be already built, designed, or at least projected. However, in theory and partially in practice, the process may be iterative; i.e., if the training required for operation of a given machine is difficult or impossible to achieve then the design of the machine may or must be changed. At the present time the information provided to the helicopter aircrew is an accumulation of all the information previously found, at one time or another, to be useful. Since this history of accumulation goes back to the earliest days of fixed-wing aircraft, it is at least possible that some of the information is unneeded or redundant. Until the advent of current simulator capabilities, there was no safe or efficient way of conducting research to reduce this accretion. Flight simulators now provide the basis for a "zero-based" approach to helicopter crew information needs. Flight simulation can be initiated with no displays other than the visual outside reference. As crew performance weaknesses and failures are observed, the type of information necessary to improve performance and prevent failure can be determined. Then appropriate sensory signals may be developed to provide the necessary information. Because this research will not have a major effect upon systems already in existence, or even those now in development, research on training methods to cope with the existing crew information systems must be continued.

10.3.5 Map Displays

Almost all maps and map displays have historically been symbolic in design, primarily because of limitations of the media, either paper or electronic. Now the potential exists for elimination of many of the restrictions inherent to paper and early electronic displays. Research is needed in this area to determine what mission-related information is required. That is, why is the map/display needed--to avoid hazards, to locate targets, to select flight routes, to return to base, or for some other function? This approach is much more important than research aimed at incremental improvements in map displays. Ideally the aircrew should be provided with only that portion of the map information which is relevant to the task or tasks at hand at any given time. This of course is now easy to achieve with electronic displays in which unneeded information can be suppressed, scales and orientation changed, and emphasis added, either by programming or crew choice.

SECTION 11 FINDINGS

The primary findings of the study are summarized in this section. These findings are presented under the same headings as the sections in the main body of the report from which they are derived. The rationale supporting each of the findings may be found in those sections.

11.1 SURVEY RESULTS

(1) Training requirements will change gradually, but the cumulative effects will alter all aspects of training.

(2) The importance of physical skills will be reduced, but the decision workload will increase, so that crew members will continue to be taxed almost to the limits of their abilities.

(3) Cathode ray tube (CRT) displays will replace outmoded dials, reducing cockpit information clutter.

(4) The mast-mounted sight will result in a trade-off between reduced vulnerability to enemy action versus some increase in ground collision hazards.

(5) The full complement of new targeting subsystems will revolutionize night and all-weather combat capabilities, and will markedly alter the nature and amount of training for these conditions.

(6) Navigational abilities in night NOE flight are a very serious concern.

(7) The Pilot Night Vision System, the Target Acquisition and Designation Systems, and Head Up Display alter the cues now normally used in piloting and combat activities, and will require corresponding changes in training.

(8) Pilot coordination of images from different displays with visual perception of the external environment may pose significant problems, including severe disorientation.

(9) If a tilt-rotor configuration is accepted for the SEMA-X, or any other future Army aircraft, special training will be required for the transition regime from hover to forward flight and the reverse.

(10) The potential for air-to-air combat between helicopters in future wars poses a very serious training problem because there is no foundation of combat experience upon which doctrine for this role can be built, and without such doctrine, training needs cannot be determined.

11.2 SCORING MODEL EVALUATION

The scoring model evaluation produced a large amount of detailed information concerning the relative importance to training of the many factors involved in the introduction of new Army aviation systems.

This information tends to be specific with regard to each factor, each combination of factors, and each system and subsystem. These evaluations were

used in the subsequent development of training needs and do not lend themselves to a separate synopsis. Therefore, it is recommended that Section 5 be reviewed by those interested in the evaluation of individual system training needs, or in the relative importance of a given factor among all systems.

11.3 SYSTEM AND SUBSYSTEM CHARACTERISTICS

The information provided by Army personnel with respect to the training-related characteristics of new Army aviation systems and subsystems was presented in detail in Section 3. This information concisely summarizes the salient features of each system and subsystem as perceived by highly knowledgeable persons.

Section 3 thus provides an excellent reference source for those who wish to know what characteristics of future Army aviation equipment are most likely to influence training requirements.

11.4 SYSTEM ELEMENTS WHICH WILL ALTER TRAINING REQUIREMENTS

(1) New technologies for the display of information were identified as the system element most likely to bring about changes in training needs.

(2) Changes in target detection and acquisition systems will also have a major effect on training.

(3) Automation of many manual flying activities will shift crew duties toward management of the helicopter as a combat system, with correspondingly less emphasis on some flying skills.

(4) Nap-of-the-Earth flying may remain the most critical of all training requirements.

(5) Both the Near-term and the Far-term Scout Helicopters will require radical changes in training methods for air-to-air combat and target detection and attack.

(6) The Army Digital Avionic Systems, Integrated Digital Systems Validation, and Advanced Digital Optical Control System will substantially alter methods of training for NOE flight, navigation, and instrument flying.

11.5 CHANGES IN TRAINING REQUIREMENTS

(1) As CRT displays become increasingly sophisticated, less training will be required for pilot adaptation to cockpit instrumentation configurations. Training will shift to emphasize pilot ability to recognize information needs and call for such information to be displayed. Instrument scanning for system condition and checkout will be replaced by automation, greatly reducing training needs in this area.

(2) Books, lectures, static display models, and cockpit replicas will be substantially replaced by computer controlled CRT training devices and computer-assisted-instruction. Training will be directed toward the positive reinforcement mode, minimizing opportunities for incorrect responses.

(3) Special training will be required to prevent vertigo and disorientation associated with the requirement for crew integration of the multiple images of the new displays with the visual perception of exterior references.

(4) Basic flying training time may be reduced in favor of increased training for combat operations, much of which can and will be done in simulators.

(5) Many combat tasks, such as target detection and attack, will be performed on the basis of information presented in electronic displays. Therefore, the need for flying time and full-task simulation training in these skills will be reduced in favor of part-task trainers simulating only the display and the specific task controls, at least until part-task proficiency is fully achieved.

(6) Full-task training for combat operations must include realistic threat simulation, must require the simultaneity of actions involved in actual operations, and should attempt to introduce the psychological aspects of combat.

(7) Training for adverse weather operations will require an increasing portion of curriculum time.

(8) Increased night-time NOE operations will require substantial efforts to develop new training methods and devices. Very possibly these operations will also require selection of personnel with special aptitude for night operations.

(9) Rapid deployment operations will necessitate greater training emphasis on several tasks associated with such operations. Examples of such tasks are long-range navigation, in-flight refueling, and heavy-lift helicopter operations.

(10) Changes in the characteristics of the population pool available to meet Army aviation needs may require alterations in methods of selection as well as in methods of training. The direction of selectivity, regardless of variations in supply and demand, should be continuously toward identification of those abilities and aptitudes specifically associated with Army aviation, and selectivity should consider only those so identified.

11.6 PERSONNEL AVAILABILITY

(1) Conditions which would decrease total Army accessions and/or increase demand relative to present levels could increase the Army aviation aircrew demand to 27 percent of the total Category I and II male accessions. This would place severe strains on training and standards, would greatly affect other Army personnel needs, and would result in pressures to increase the number of women in the helicopter trainee program. Continuation of the present level of training of 1,650 helicopter pilots annually should not require significantly different standards of acceptance nor pose major problems in obtaining trainees. However, this statement is true only if total Army accessions can be maintained near current levels.

(2) The best currently available model for predicting Army personnel accessions, the Fernandez model described in Section 8, is based on data for

the period 1971 to 1979. The population base in that period is very different from that which will exist in the 1982 to 2000 period, and therefore makes predictions based on the Fernandez model invalid. Problems in Army staffing will be much more severe than any forecast using the Fernandez model would indicate.

11.7 BEHAVIORAL RESEARCH REQUIREMENTS

The final objective of this study is the determination of specific behavioral research efforts needed to support the development of future Army aviation training programs. Therefore, the summary of findings with respect to this objective is presented in the next section, "Areas suggested for Research Effort".

SECTION 12
AREAS SUGGESTED FOR RESEARCH EFFORT

The findings of this study with respect to identification of behavioral research which needs to be conducted to support development of future Army aviation training are described in the following paragraphs. These suggestions are derived from the information obtained from the interviews with Army personnel and from the review of pertinent literature, together with the use of the scoring model evaluation, as described in the prior sections of this report. Priorities for research and a structured program are not included since these are properly the responsibility of the Army to determine and thus were not intended to be a part of this study. However, the information presented in this study should provide at least a partial basis for the development of priorities and structuring of research programs. The synopsis of suggested research in this section contains only the major highlights. Additional suggestions and supporting information were given in Section 10.

(1) The appropriate balance between simulator training and flying practice has yet to be determined. Research to define this balance should include controlled experiments comparing objectively measured performance, evaluation of trainee perceptions of confidence, and determination of amount and type of actual flying needed to meet aircrew psychological needs.

(2) Behavioral research is needed to determine the optimum integration of visual, auditory, and tactile sensory inputs. This research should be directed toward practical applications in cockpit design.

(3) Further research is needed on aircrew behavior at the limits of workload saturation. Topics of importance are saturation of information processing ability, exceeding of action response times, and crew failure modes.

(4) Operations research is needed to define the trade-off between ground environment impact losses and losses from enemy threats for various speeds and altitudes. This information must then be provided to commanders and aircrews to guide doctrine and tactics.

(5) The possibility, and potential gains, of reversing the training sequence, so that instrument flight training in simulators precedes visual flight training in aircraft, should be examined. The importance of this question is emphasized by the fact that most "washouts" occur during instrument training, after substantial costs have been incurred in actual flying training.

(6) Detailed flight task requirement analyses of night NOE, air-to-air combat, and rapid deployment operations are required to support development of training programs.

(7) Research is needed on the physical and psychological characteristics which are important in night flight operations. This research should support development of crew selection methods, training programs, and operational doctrine for day and night operations, including examination of the concept of separate squadrons for day and night employment.

(8) Most research on NOE operations has concentrated on terrain and vegetation conditions which facilitate helicopter concealment. Therefore research is needed on NOE capabilities in relatively flat, treeless terrain, and in built-up metropolitan areas.

(9) Behavioral research is needed on close-formation helicopter flight factors, including the mental concentration, near-field distance perception, and flying skills required in high-stress combat environments.

(10) Determination of aptitudes for information processing and decision-making tasks will require substantial research support as aviator workloads involve increasing amounts of such activities.

(11) Optimization of cuing systems in CRT displays will require a basis of fundamental understanding of human response to a sequence of task-related visual abstractions. Applied research in this area will have great difficulty in breaking away from past instrumentation practices and ingrained aircrew habits.

(12) One useful research approach to the determination of helicopter crew cockpit information needs could use a "zero-base" concept. That is, flight simulation could be initiated with no cues other than external visual references. Then incremental units of information would be added only as necessary to prevent failure or improve performance. This might well lead to a different hierarchy of cockpit information cues than the present system, which is the result of instrument accretion.

(13) Research is needed to identify the types and amounts of mission-related information that are required on maps and map displays, particularly for NOE operations. This research should consider the potential which electronic displays have for suppressing of unneeded information, changing scale and orientation, and emphasizing specific items.

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